Work Package 4.1
Monitoring case studies in Italy
Trezza San Pietro

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Titles:

D4.1.1 Explorative survey with multibeam echosounder (MBES) and/or ROV/scuba
D4.1.2 Set up of an integrated monitoring system in situ
D4.1.3 Images and data transferred at land and visualized through different media
D4.1.4 Investigations through MBES carried out during the testing phase
D4.1.5 Extension of monitoring execution to other parameters (i.e. biological components)
D4.1.6 Collection and reporting of obtained data

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EXECUTIVE SUMMARY

This report describes the results of a survey carried out from November 2019 until September 2021 in the area of the Case Study "Trezza San Pietro", natural rocky outcrops located offshore Grado (Northern Adriatic Sea), Italy. Monitoring of reefs is essential for the continuous evaluation of their structural and ecological evolution, hence their capacity of sustaining different economic activities, in line with the principles of Blue Economy. This activity, funded by the EU through the Interreg Italy-Croatia CBC programme, was initiated in recognition of the underexploited potential for sustainable use of some natural and artificial reefs located in the Adriatic Sea and is part of ADRIREEF (Innovative exploitation of Adriatic Reefs in order to strengthen blue economy) project.

• Aim of the survey is a transborder investigation aimed at highlighting the unexploited potential of 7 selected reefs, natural or artificial, located offshore the Italian and Croatian coasts of the Adriatic Sea.

• During the survey, innovative technologies with low environmental impact were tested, based on the outcomes of ADRIREEF WP3.4 “Identification of technologies for underwater monitoring of reefs”. However, a few modifications may have been introduced to reflect Case Studies specifics or to address unexpected situations occurred during practical activities at sea.

• The morphological survey has been carried out with the last generation multibeam echosounder, Reson Seabat 7125; with this instrument, 512 beams equidistant on the seafloor are achievable simultaneously with a ping rate up to 50 pulse per second.

• The technologies used in monitoring the "Trezza San Pietro" Case Study were: underwater camera and annexes (underwater lamp,...), Turbidity probe with integrated wiper, CTD multiprobe IDRONAUT 316 Plus, solar panel, rechargeable battery, data logger and Modem, Acoustic Doppler Current Profiler.

• The scope of this work also includes an assessment of the potential reef vocation for the specific CS (e.g. tourism, farming, aquaculture, fishing, environmental safeguard,...).

The main findings of this study were as follows:

The overall results suggest that the natural reef named "Trezza San Pietro" provides important ecosystem functions by representing a hot spot of biodiversity and offering refuge to fauna of commercial value to fisheries. The services provided by this natural reef could encourage the development of new sustainable economic activities according to the principles of the Blue Growth. After the monitoring phase and after considering the general features of the reef it seems that the most suitable activities to be implemented in the area would be the scuba diving, the professional small-scale fisheries with set gears, and the recreational fishing (e.g., fishing trips, fishing tourism). All these activities should be developed with adequate planning and management, in order to preserve the environment, to avoid the overexploitation of the reef resources, and to coordinate those activities which could spatially conflict. The potentiality are high because natural reefs which are similar to the Case Study are abundant and widely spread in the northernmost area of the Adriatic Sea.

1. INTRODUCTION

The investigated area is located in the Gulf of Trieste (Northern Adriatic Sea), in a maximum water depth of 18 m, close to the Slovenian-Croatian coast.

From the stratigraphical and depositional point of view, the study area is characterized by sedimentary deposits interpreted as late Quaternary Transgressive Systems. They are represented by LST (Lowstand System Tract) alluvial clays and sands of continental origin, buried by sediments displaying different thicknesses that constitute the TST (Transgressive System Tract) deposits, mainly characterized by "barrier-lagoon-estuary " systems (Trincardi et al., 1994). The seismic stratigraphy and tectonic evolution of the Gulf of Trieste is described in detail in Busetti et al. (2010).

The seafloor sedimentary deposits show a gradual increase of the fine fraction from the coast towards the offshore; then a progressive increase in the coarse fraction in the central part of the study area (residual sands of the TST) is recognized.

The most peculiar features of the Northern Adriatic Sea are submarine rocky exposures, irregularly distributed on the sea bed, locally known as "trezze" in Friuli Venezia Giulia, "tegnùe" in Veneto and "grebeni" or "bromboli" in the Istrian region (Slovenia and Croatia).

The Natural Reef "Trezza San Pietro", selected as Case Study, is located 8.7 Km from the coast, offshore Grado harbour (northern Adriatic Sea), facing the coastal plain shaped by the Isonzo river at East and the Grado and Marano Lagoons at the West. The area is mainly exposed to SE and NE winds and receives nutrient-rich fresh water input from the Isonzo and Tagliamento rivers. The NR is located at a bottom depth between 15 and 16 m, with a reef edge of 0.2-0.9 m. It covers an area of about 9850 m^2, comprising small reef structures protruding from the sediment (patch reef). The surrounding sediments are mainly detritic and sandy.

The site that has been chosen is representative of a vast series of rocky outcrops extending all over the Northern Adriatic, approximately from offshore Grado to the offshore area of the Po river delta. Similar structures have also been documented offshore the western coast of Istrian peninsula. From recent investigations about 250 outcrops have been identified only in the Gulf of Trieste, between Punta Sdobba and Punta Tagliamento; the most widespread range of these outcrops is on the seabed in front of the lagoons of Grado and Marano at a distance from the coastline between 2 and 17 km, and a depth varying between 8.3 and 21.5 m. They extend from a few to several hundred meters and are characterized by different substrata (clastic sedimentary, sedimentary sediments, organogenic). Their origin is still largely debated, since not all of them can be assimilated to bioconstructions, and in some cases they are constituted by slabs deriving from the cementation of sand or rocks by methane gas. These rock formations have been initially interpreted as beachrocks (Stefanon, 1970; Newton and Stefanon, 1975), while the current hypothesis on their genesis suggests they are most likely related to seeping methane and cementation and lithification processes (Gordini et al., 2002; Donda et al., 2015). The calcareous concretions are attributable to Corallinageous algae and secondly to Briozoans, Molluscs (especially *Arca noae* and *Chama gryphoides*), Anthozoans (*Cladocora caespitosa*) and Serpulid Polychaeths.

The main professional fishing activities conducted in the vicinity of "trezze" environment include harvesting the smooth clam *Callista chione* with hydraulic dredges and artisanal fishing with a wide variety of set nets.

Regarding an administrative point of view, in 2012 the natural reef site was proposed by the council resolution 1623, pursuant to Regional Law 7/2008, art. 7, as the new site of community importance it3330009 "Trezze San Pietro e Bardelli". Nevertheless it was necessary to await the European Commission Decision 2015/69 / EU of 03.12.2014 which ratified the insertion of the site in the list of SCI of the continental biogeographical region. The process that has been virtuously since 2015 and now the SCI is part of the Natura 2000 Network.

The efforts made for a correct and updated description of the site are justified by the potential to develop underwater tourism. The considered site is only an example of the numerous sites of similar nature found in the waters of the northern Adriatic. This means that the tourist package for divers designed for the “San Pietro” site could be replicated on other sites. The underwater tourism can act as a driving force for the development of related activities such as boating, hotel offers, centers for sales and rental of diving equipment. Nevertheless, any kind of economic development and use of the natural reefs should take account of the fishing activities occurring on the same sites. The different economical activities should be managed in order not to compete, but, rather, to reinforce each other. As example, fishermen could be involved to craft the divers on the sites or to offer a “double package”: diving and fishing touring. The direct involvement of the fishing sector would make it possible to lighten the fishing effort on these natural sites without damaging the fishermen's income. Another positive aspect could be the increase of fishermen's conscience and sense of responsibility inducing them to become a sort of guardians of the sites. In this framework the natural reefs could become a virtuous example of blue economy.

2. GEOMORPHOLOGICAL MAPPING

2.1. Description of equipment and acquisition/processing techniques

The survey has been carried out with the last generation multibeam echosounder, Reson Seabat 7125. The proposed methodology is the result of many years of OGS’s experience, developed and tuned on multiple research and service projects, in Italy and in foreign countries, issued with multibeam echosounder.

A complete multibeam system is made by six fundamental components, each one basic to have a good final data.

1. The sonar Processor
2. The transducer
3. The Motion Reference Unit and Gyro
4. The differential GPS
5. The speed of sound probe
6. The acquisition software

The sonar processor Reson Seabat 7125 is the main core of the system; it generates the electric pulse that is converted by the transducer in acoustic pulse. The transducer is made by two parts: projector and receiver; the return-echos are converted by an hydrophone array to electrical signals that are decoded by the sonar processor to obtain, thanks to a beam forming technique, the final data: 512 points. To correct these points the system has to know precisely, for each pulse, the vessel attitude in terms of pitch, roll, heave, yaw; this is the task of the Motion reference unit model MAHRS, producted by TSS-TELEDYNE. The roll value is also used to steer the acoustic pulse so to insonify allways the nadir area of the seafloor.

The maximum ping rate of the Reson 7125 is 50 Hz so all the data have to be perfectly synchronized by the electric pulse 1 pps (1 ping per second - 5 ns length) generated by the differential GPS model DSM232 produced by Trimble. The differential GPS provides a decimetric position, using the Omnistar HP service, for an accurate georeferentiation of the final data.

To know the correct path of the acoustic pulse in the water, it is important to measure the local speed of sound of the water. For this purpose there is a real time probe that continuously measures and sends the speed of sound close to the transducer, beside, at the beginning of the survey there is the necessity to measure this speed along the water column with a profiler probe.

The final data are sent from sonar processor to the acquisition software Reson PDS2000 for georeferentiation and vessel's attitude correction.

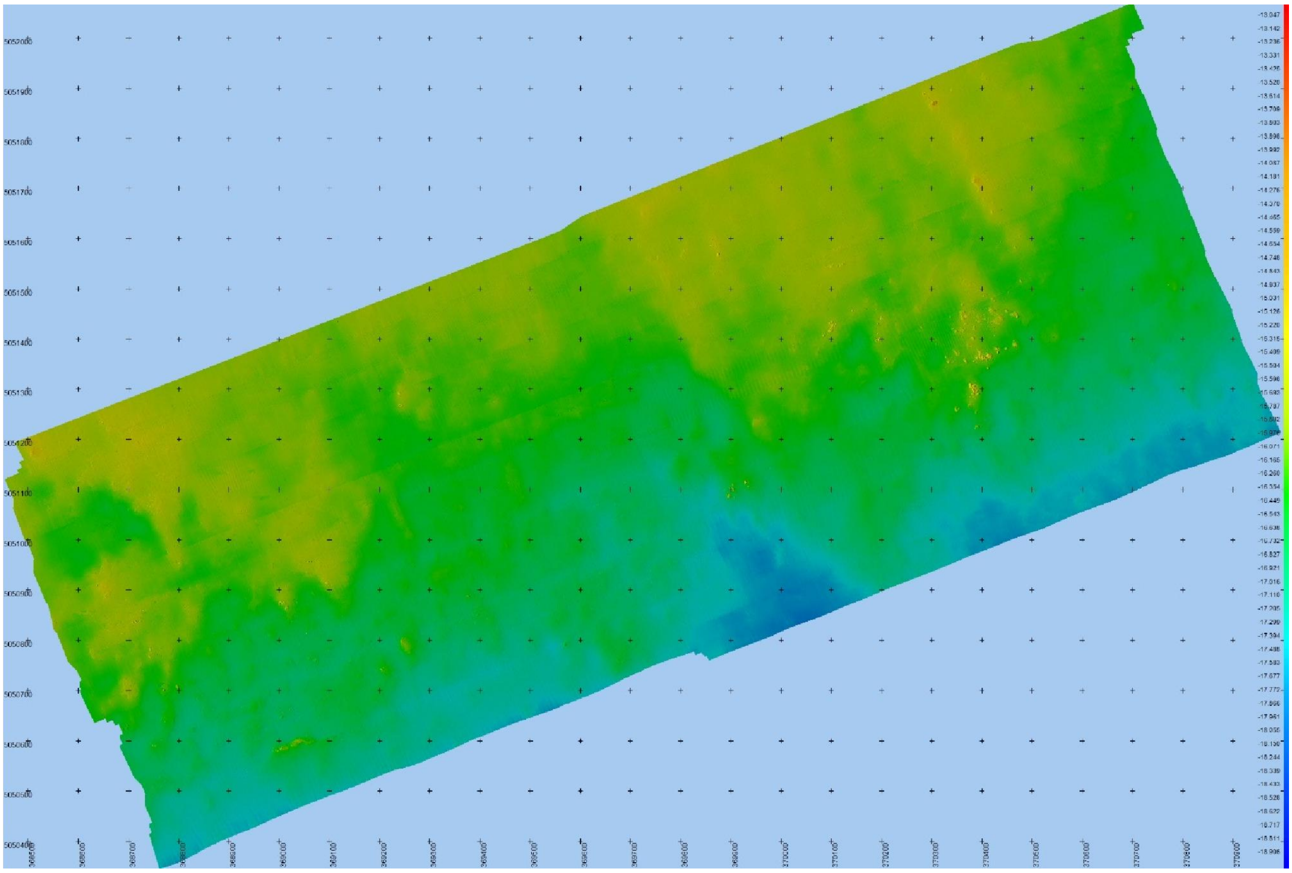
2.2. Survey results

The "San Pietro" outcrop lies at a distance of about 9 km from the coast, at 15 m depth. The study of this structure was carried out for the first time in the context of previous research projects and in particular the Interreg TRECORALA project through a Side Scan Sonar (SSS) survey (Edgetech DF-1000/DCI, 100-500 kHz; data processing: Coda Octopus Geokit Mosaics; cell size: 50 cm) which covered a 4 km^2 area. As part of the ADRIREEF Project, the area of approximately 2 km^2 was mapped and expanded through high-resolution multibeam surveys on 16, 17 and 21 September 2020. The data highlights that the sea bed is almost flat, locally showing the occurrence of rock outcrops, with a range of sizes, shapes and spatial orientations. The sea bed is mainly composed of sands.

The surveyed area shows a NW-SE, 1,5 ‰ dipping sea floor, with a depth ranging from 15 to 17 m. The rocky outcrops have a pinnacle morphology and are 1.5 to 1.9 m high, and 1 to 5 m wide.

The rocky outcrops can be grouped in two blocks with 40 smaller (0.6 up to 6 m in length) outcrops in the surroundings, covering an area of 7000 m^2 (about 175 m x 75 m; E-W oriented). The larger block is 260 m^2 large (29 m x 11 m).

These rock outcrops are characterised by a rich community of associated flora and fauna, thus representing a unique hotspot of biodiversity on the rather monotonous seabed of the Northern Adriatic Sea. The coralligenous biogenic concretions that characterize these reefs play a fundamental role as habitat for reproduction and nurseries of demersal and pelagic species. Nevertheless these structures are very sensitive to human impacts. Scuba diving confirmed the widespread fragmentation of these features, probably as a result of harvesting the bivalves *Callista chione* Linnaeus, 1758 and *Venus verrucosa* Linnaeus, 1758 with hydraulic dredges.



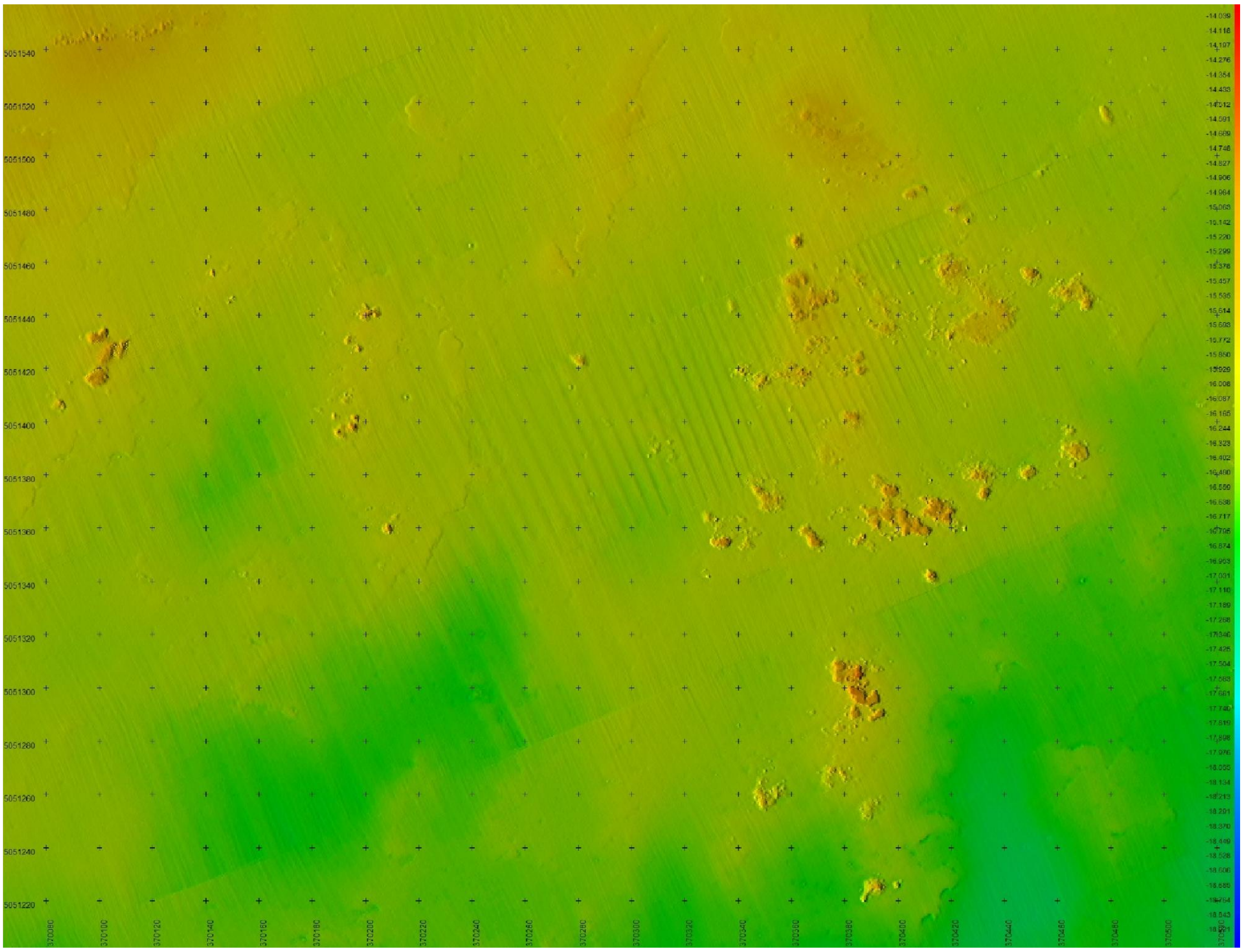


Figure 1 - Multibeam sonar bathymetric map and 3D perspective view of "San Pietro" outcrop area, 1.6 km² wide. The surveyed area shows a NW-SE, 1,5 ‰ dipping sea floor, with a depth ranging from 15 to 17 m. The rock outcrops have a pinnacle morphology and are 1.5 to 1.9 m high.

3. SAMPLING TECHNIQUES AND METHODS OF ANALYSIS

The measurement of physical parameters (intensity of flows and direction, temperature, salinity, turbidity and dissolved oxygen) of the water column was carried out at different temporal and spatial scale by fixed near-real time oceanographic observing system buoys (Chapter. 3.1 - Speed and direction of water currents; Chapter 3.2 - Water column parameters) and by means of oceanographic monitoring of the water column by monthly cruises in the vicinity of the Case Study (Chapter 3.2 - Water column parameters). The following Table 1 better explains the measurements developed.

Table 1 - Different parameters registered during the Monitoring phase of the Case Study "Trezza San Pietro" related to the observing systems deployed in the Gulf of Trieste.

Parameter	**Buoy MAMBO 2** (continuous, August-September 2021)	**Buoy MAMBO 3** (continuous, August-September 2021)	**ARPA CTD profiles** (monthly, November 2019 - March 2021)
ADCP	X	X	
Temperature (surface)	X	X	
Temperature (close to bottom)	X		
Turbidity (close to bottom)	X		
Temperature (at 10 m depth)	X		
Salinity (at 10 m depth)	X		
Oxygen (at 10 m depth)	X		
Turbidity (at 10 m depth)	X		
Temperature (water column)			X
Salinity (water column)			X
Dissolved Oxigen (water column)			X
Clorophyll (water column)			X
Turbidity (water column)			X

The most interesting physical parameters on the water column at the Case Study are: Temperature, Currents and Turbidity. This is because one the main vocations of this natural reef is the developing of underwater tourism. The evolution of Temperature during the year is fundamental to prepare scuba divers and to indicate adequate diving suits. Nevertheless, Turbidity and Currents are fundamental physical parameter that could seriously compromise the visibility on the site or the security of the diving trip, respectively.

The original plan was to describe the physical parameters of the water on the Case Study using an existing buoy moored in the vicinity of the natural reef (MAMBO 4, coordinates 45.610°N; 13.343°E) (Fig. 2). The buoy was a meteorological station and was registering the sea water temperature only at the surface. The intention was to integrate the buoy with a thermometer and a turbidity probe in the vicinity of the bottom and to equip the buoy with solar panel, rechargeable battery, and a data logger with a Modem. This setting would enable continuous sampling, on a frequency of 15 minutes, and would ensure the collection of water parameters and real-time data transmission. Information about the oceanographic characteristics on the site would be helpful to the planning of diving activities, as it permits to *a priori* evaluate those parameters crucial for a safe and nice dive, such as temperature, currents and turbidity.

Nevertheless, the original plan encountered a lot of difficulties and accidents. The purchasing of the turbidity probe and the other electronic components was much more time consuming than expected. Later, due to the Covid-19 pandemic constrains, it was impossible to reach the buoy, perform routine maintenance of the buoy and implement the tools foreseen for the project purposes. After that, in October 2020, the oceanographic buoy was stranded by a strong storm and it was seriously damaged, without the possibility of being repaired in a short time.

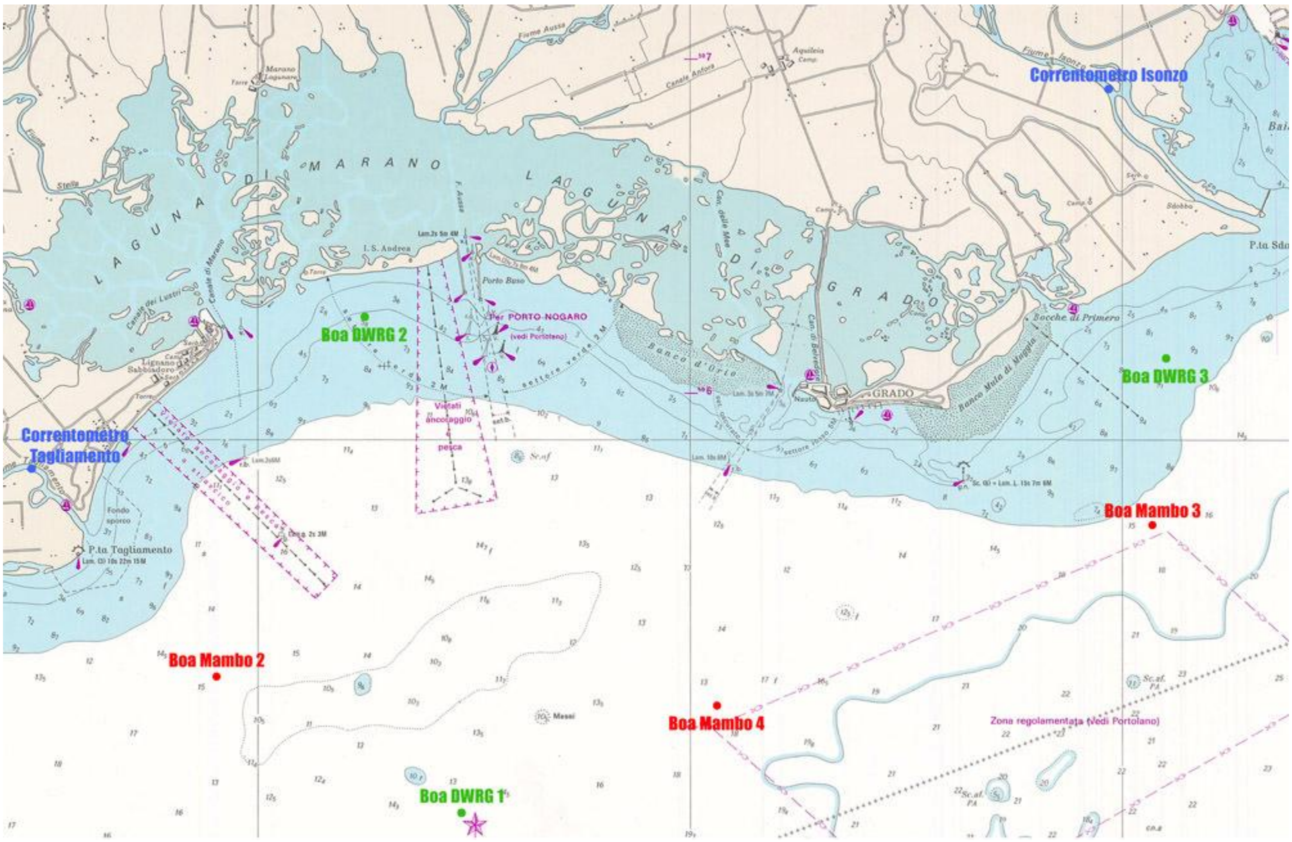


Figure 2 - Map of the Gulf of Trieste, where oceanographic buoys are indicated.

Thus, as a compensatory solution, it was decided to implement the registering system on another buoy (MAMBO 2, coordinates: 45.603°N; 13.151°E), which was moored about 9.5 miles from the natural reef (Figure 2), on similar depth (15 m depth) and bottom typology. This solution was adopted to test the feasibility of the continuous monitoring of the physical properties and especially to test the real-time transmission of the data at land.

Since 29 July 2021 the oceanographic buoy is registering in continuous modality and it is successfully transmitting to the laboratory the following water column parameters:

- Temperature at surface
- Intensity and direction of currents along the water column registered by the Acoustic Doppler Current Profiler (ADCP)
- Temperature, Oxygen, Turbidity (at 10 m depth)
- Temperature and Turbidity close to the bottom (at 15 m depth, 2 m from the bottom)

The turbidity sensor (Figure 3) required a calibration which was carried out in the OGS laboratory (Figures 4, 5, 6).

Figure 3 - Turner Turbidity probe purchased with ADRIREEF project funds.

Figure 4 - Turner Turbidity probe mounted with other instruments.

Figure 5 - Testing the probes in laboratory.

Figure 6 - Testing the connections of the probes in laboratory.

3.1. Speed and direction of water currents

Intensity and direction of currents along the water column were registered by the Acoustic Doppler Current Profiler (ADCP) mounted on the oceanographic buoy MAMBO 2 and data were transmitted since 29 July 2021. Due to some technical problems and in order to describe more adequately the current on the site, another data set continuously recorded on the buoy MAMBO 3 (45.644°N; 13.511°E) was considered.

The ADCP instrument measures the reflection of an acoustic signal from particulate matter drifting in the water column. The amplitude is the strength of the return signal for each beam and it decreases with the distance from the instrument, establishing that way the maximum usable range (during this monitoring it was the bottom detection). The ADCP has been fixed to the buoy at a depth of 2 m, and was programmed with 1 meter wide cells where the currentometer was measuring the current by means of acoustic signals. All the speed, direction and amplitude data were stored as raw data for each of the cells.

3.2. Water column parameters

The measurement of water column physical (temperature, salinity, and turbidity) and bio-chemical (nutrients, dissolved oxygen and chlorophyll as fluorescence) parameters other than current speed and direction was carried out at different temporal and spatial scale, by the fixed near-real time oceanographic observing system (see Chapter 3.1) and by means of oceanographic campaigns.

Since 29 July 2021 the continuously registered and transmitted parameters on the buoy MAMBO 2 were:

- Temperature at surface
- Intensity and direction of currents along the water column registered by the Acoustic Doppler Current Profiler (ADCP)(see Chapter 3.1)
- Temperature, Oxygen, Turbidity (at 10 m depth)
- Temperature and Turbidity close to the bottom (at 15 m depth, 2 m from the bottom)

Additionally, another data set continuously recorded on the buoy MAMBO 3 (45.644°N; 13.511°E) was considered.

To adequately characterise the water column parameters on the Case Study during a wide time period, we used the data collected by ARPA FVG on a sampling station close to the natural reef. The station (coordinates 45.625°N; 13.329°E) is 2.5 Km far from the Case Study and it is monitored on a monthly basis. The following water column physical parameters (temperature, salinity, conductibility, pH, Optical Dissolved Oxygen, PAR, chl-a and turbidity) were sampled continuously from the surface to the sea bottom by using a CTD multiprobe IDRONAUT 316 Plus:

- Pressure (Decibar);
- Temperature (°C);
- Salinity (psu);
- Dissolved Oxigen (ml/l);
- Ph;
- Clorophyll (µg/l);
- Turbidity (ftu).

A total of 15 CTD profiles were taken monthly from November 2019 to February 2021. The only missing month is March 2020, when it was impossible to sample at sea due to Covid-19 pandemic constrains. Turbidity and Clorophyll data in November 2020 are missing due to technical problems occurred. In April 2020 the CTD profile was measured on a deeper station (coordinates 45.618°N; 13.565°E), slightly far from the Case Study; in this case only data above 14 m depth were considered for comparison.

3.3. Benthic community settled on the reef

The photographic samplings of the macrobenthic community by use of a standard frame settled on the reef was performed during two different seasons, choosing the more suitable conditions for diving and checking the organisms assemblages. Winter condition was sampled in February 2020. Summer condition was sampled in June, July and at the beginning of October 2020.

The underwater photos acquired in georeferenced positions had a minimum resolution of 20Mpx and were taken both with free technique (minimum 10 photos per relief) and with the use of a standard frame (25 x 25 cm, minimum 12 photos per relief) which acts as a frame for the photodetection of epibenthic flora and fauna.

Photographic samplings of fixed frame areas at georeferenced points were performed in each of the following conditions: (1) geographic exposition: north-south gradient consisting of three level corresponding to three sampling areas allocated at the north, central and south-side of the reef; (2) substrata inclination: two levels, “horizontal face” and “vertical wall”. On each survey 72 replicates (36 for the “horizontal face” and 36 for the “vertical wall”) for each geographic exposition were collected. The images were analysed with Image Analysis systems (PhotoQuad or similar), considering (1) coverage (cm^2) and (2) species number as variables to be registered.

3.4. Fish assemblage

The fish assemblage was assessed by Underwater Visual Census (UVC) with scuba divers on a seasonal basis, taking into account different gradients and environmental conditions on the Case Study. Scuba divers' pictures and videos were used to describe the status of the fish community, but also to identify the best conditions for diving, and to promote the *trezze* as diving sites.

Two scuba divers independently operated using the “strip transect” technique, taking into account: (1) geographic exposition: north-south gradient consisting of three level corresponding to three sampling areas allocated at the north, central and south-side of the reef; (2) aggregation effect of natural reef, considering as levels “proximity to rock outcrop” and “open spaces” between the natural structures. The number of replicates considered were 3 for each level of factor, meaning 3 * 2 * 3 = 18 replicates collected on each survey.

Visual Census was repeated 3 times in each season, after evaluating the best condition for diving:

- Winter 2020: 3 sampling by visual census were completed on 6 February, 18 and 23 March.
- Spring 2020: 3 sampling by visual census were completed on 30 April, 14 May, 4 June.

- Summer 2020: 3 sampling by visual census were completed on 25 June, 23 July, 1 October.
- Autumn 2020: 3 visual census completed on 14 and 23 October, 26 November.

At each sampling, if the visibility conditions were good, underwater photos and video films with free technique were associated to support the evidence of the presence of additional fish species, as well as the characteristic habitats.

Figure 7 - Underwater video camera, illuminator and annex materials purchased with ADRIREEF project funds.

Methodological detail about the Strip Transect

This method requires the diver to swim along a transect, registering all the fish individuals he sees inside a lane with a specific width. In this monitoring activity each transect was 25 m long and 5 m width, comparable to the lengths used by Mazzoldi and De Girolamo (1997) and by Fasola et al. (1997).

Scuba diving observations (ARA) involved two transects (round trip). The first transect was carried out at a constant speed without stopping with observer's attention mainly directed to the nectonic fish species, since they are the ones that move further away in the presence of disturbance.

In the second transect the diver recorded sightings of benthic fish species, slowing down his speed in order to optimize sightings of fauna that hide in caves or ravines or is mimetic and which, being territorial, do not move much from the point of the first sighting.

During each of the passages the diver moves while keeping close to the rocks. The exact number of individuals encountered for solitary species or those moving in small groups is noted, while for species with gregarious habits it was decided to use the abundance scale.

For some species targeted by commercial fishing, the abundance of individuals was recorded taking into account the size, estimated according to size classes (Harmelin-Vivien et al., 1985).

4. RESULTS AND DISCUSSION

4.1. Speed and direction of water currents

On average, the intensity of the current during the investigated periods was 0.057 m s^{-1} at 2 m depth, with 2 peaks just below 0.30 m s^{-1} (Fig. 8). From 3 to 4 m depth the mean speed of the current slightly decreased to 0.045 m s^{-1} with some peaks around 0.20-0.25 m s^{-1} (Fig. 9). From 5 to 6 m depth the current slightly increased to 0.058 m s^{-1} with some peaks around 0.20-0.35 m s^{-1} (Fig. 10). From 7 to 8 m depth the current increased to 0.073 m s^{-1} with many peaks exceeding 0.50 m s^{-1} (Fig. 11); this situation was considered not realistic. The peaks appeared even higher and more abundant in the deeper cells (data not shown in the graphs).

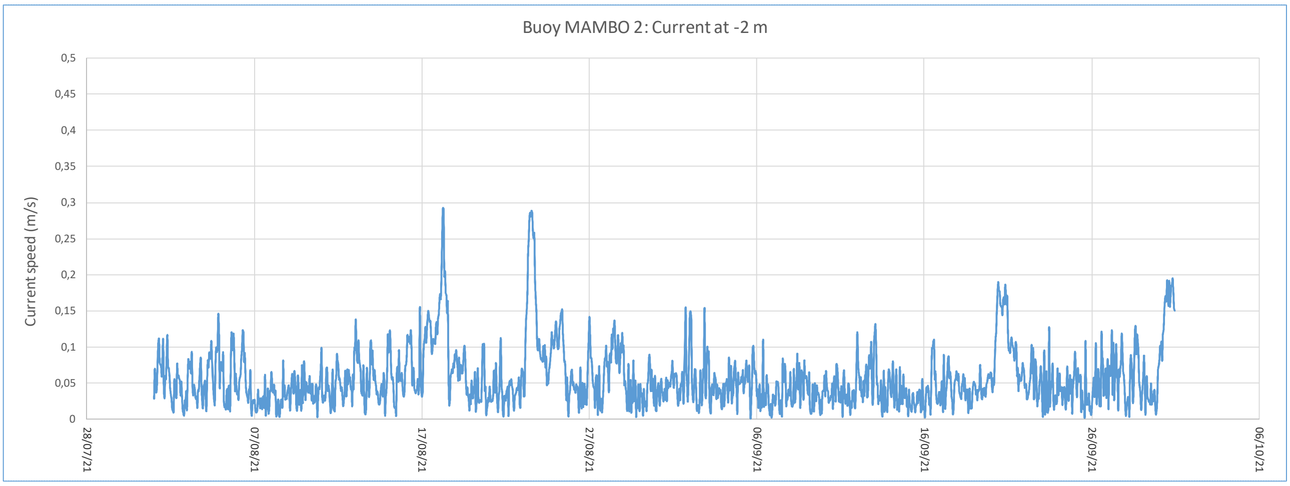


Figure 8 - Current intensity registered at 2 m depth by ADCP on the buoy MAMBO 2 from 1 August 2021 to 30 September 2021.

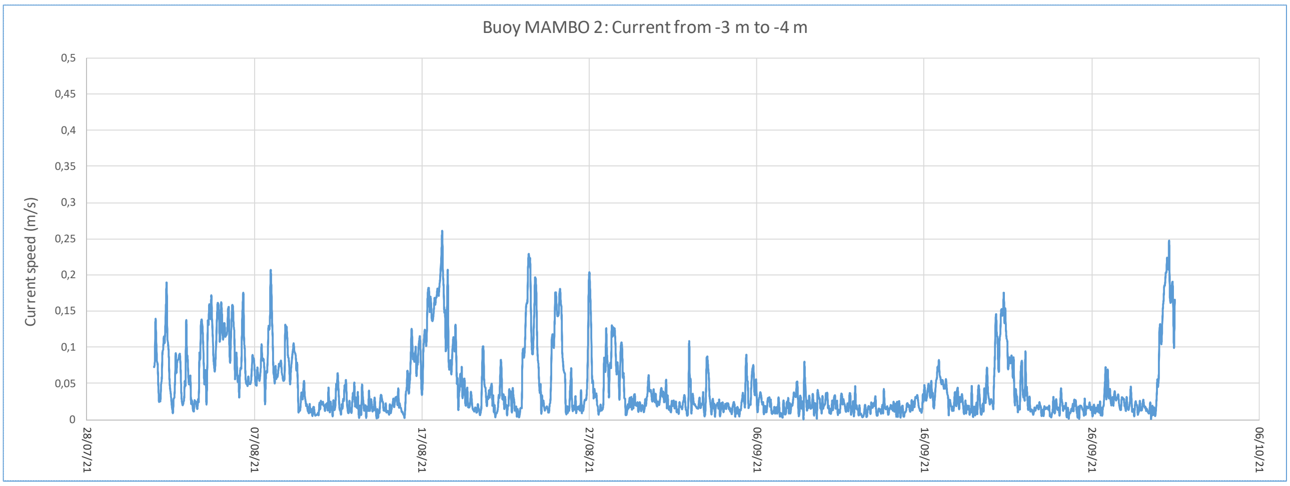


Figure 9 - Current intensity registered from 3 to 4 m depth by ADCP on the buoy MAMBO 2 from 1 August 2021 to 30 September 2021.

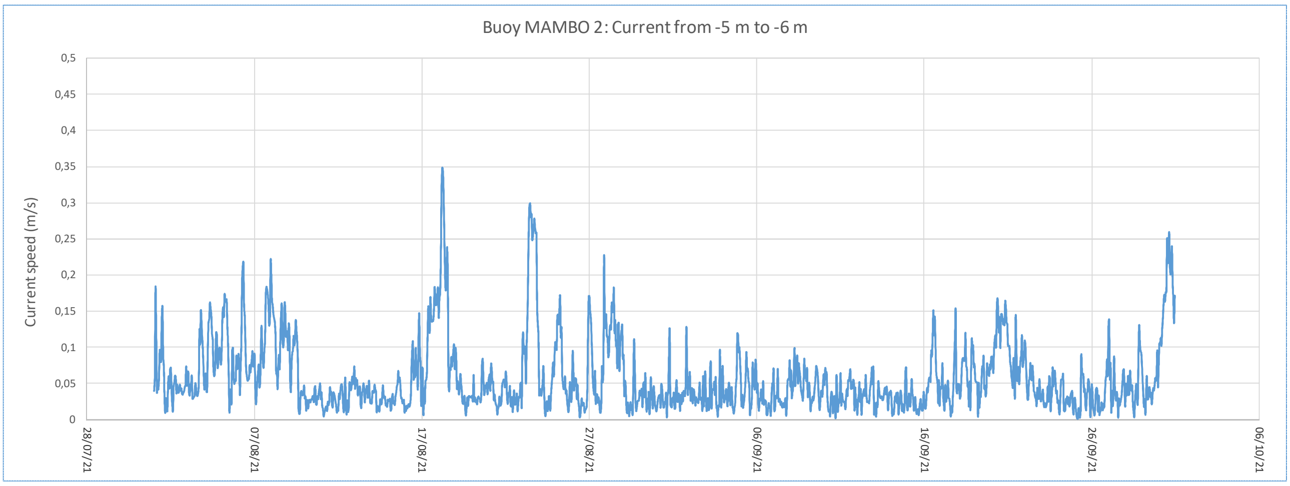


Figure 10 - Current intensity registered from 5 to 6 m depth by ADCP on the buoy MAMBO 2 from 1 August 2021 to 30 September 2021.

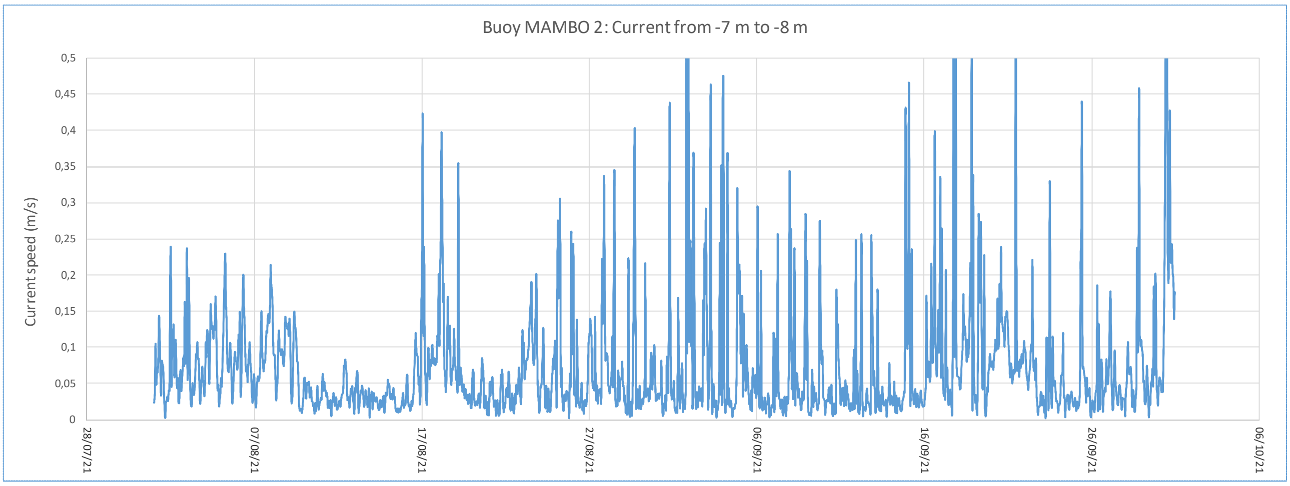


Figure 11 - Current intensity registered from 7 to 8 m depth by ADCP on the buoy MAMBO 2 from 1 August 2021 to 30 September 2021.

To describe more adequately the current on the site, another data set continuously recorded on the buoy MAMBO 3 (45.644°N; 13.511°E) was considered. This buoy is located towards East on the similar bottom depth of 15 m. Some technical problems caused missing data from 14 to 18 August and from 22 to 26 August.

On average, the intensity of the current during the investigated periods was 0.112 m s^{-1} at 2 m depth, with 2 peaks just above 0.45 m s^{-1} (Fig. 12). From 3 to 4 m depth the mean speed of the current decreased to 0.076 m s^{-1} with some peaks around 0.25 m s^{-1} (Fig. 13). From 5 to 6 m depth the current slightly decreased to 0.072 m s^{-1} with some peaks around 0.20-0.25 m s^{-1} (Fig. 14). From 7 to 8 m depth the current increased to 0.080 m s^{-1} with some peaks around 0.20-0.40 m s^{-1} (Fig. 15). From 9 to 10 m depth the current increased to 0.094 m s^{-1} with few peaks around 0.25-0.40 m s^{-1} (Fig. 16). From 11 to 12 m depth the current increased to 0.110 m s^{-1} with some peaks around 0.25 and 2 peaks above 0.50 m s^{-1} (Fig. 17).

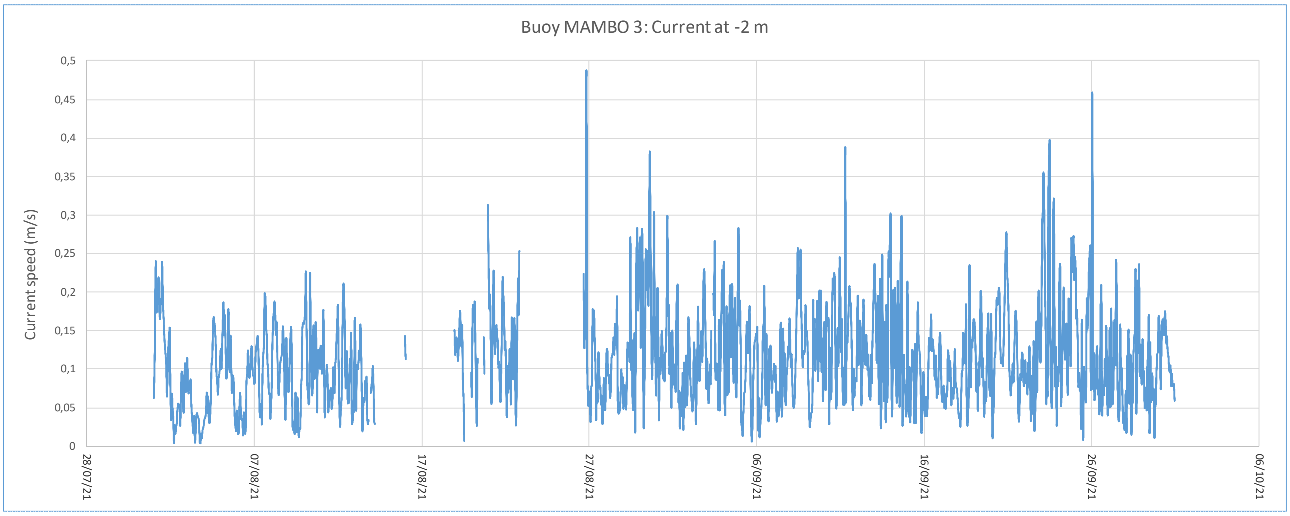


Figure 12 - Current intensity registered at 2 m depth by ADCP on the buoy MAMBO 3 from 1 August 2021 to 30 September 2021.

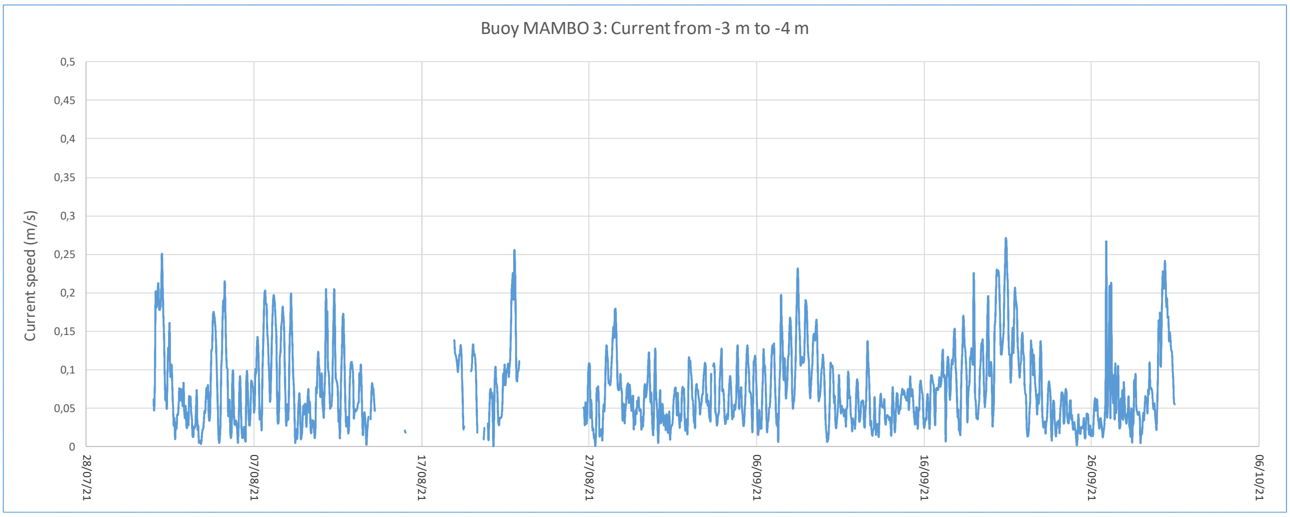


Figure 13 - Current intensity registered from 3 to 4 m depth by ADCP on the buoy MAMBO 3 from 1 August 2021 to 30 September 2021.

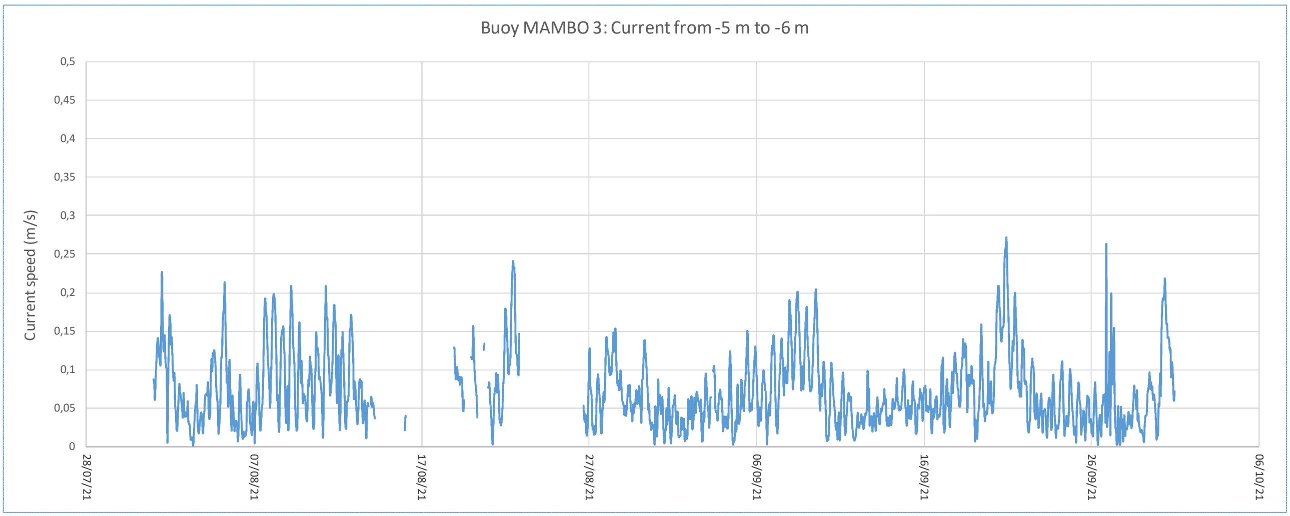


Figure 14 - Current intensity registered from 5 to 6 m depth by ADCP on the buoy MAMBO 3 from 1 August 2021 to 30 September 2021.

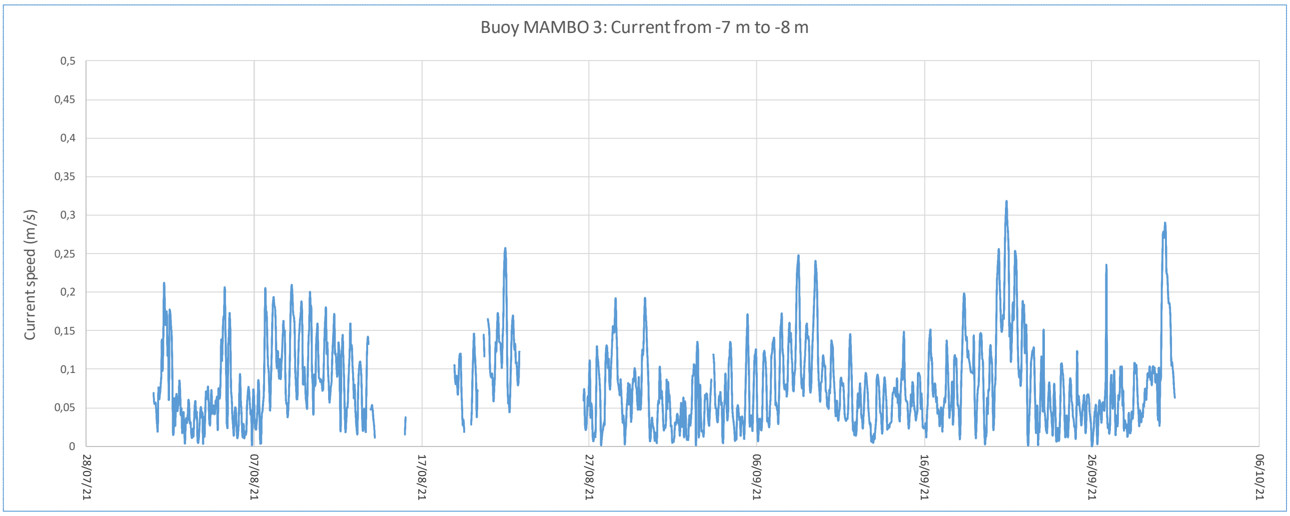


Figure 15 - Current intensity registered from 7 to 8 m depth by ADCP on the buoy MAMBO 3 from 1 August 2021 to 30 September 2021.

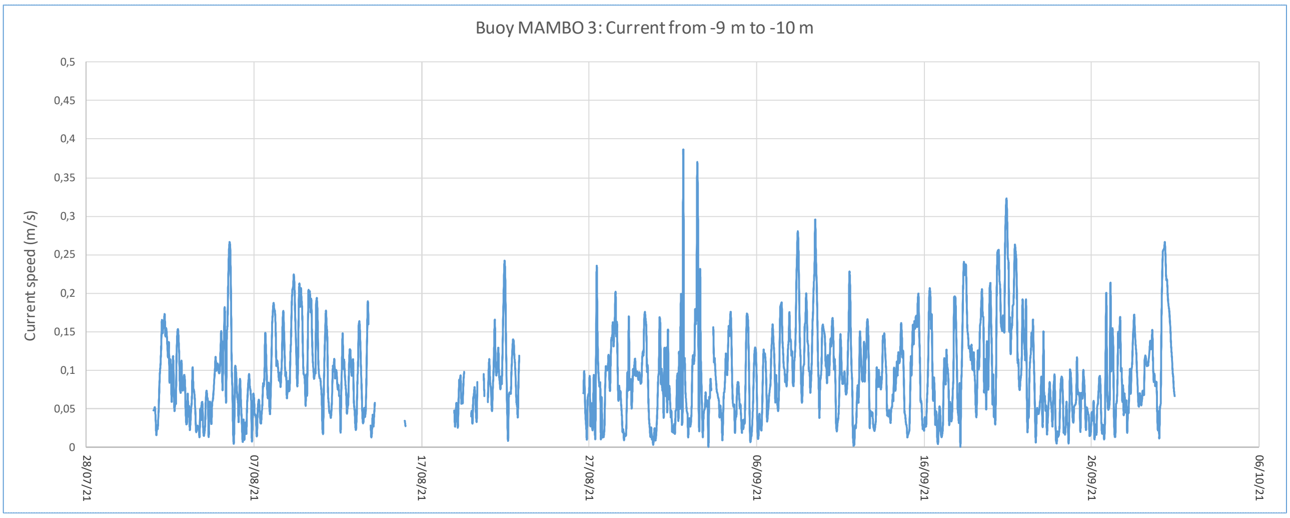


Figure 16 - Current intensity registered from 9 to 10 m depth by ADCP on the buoy MAMBO 3 from 1 August 2021 to 30 September 2021.

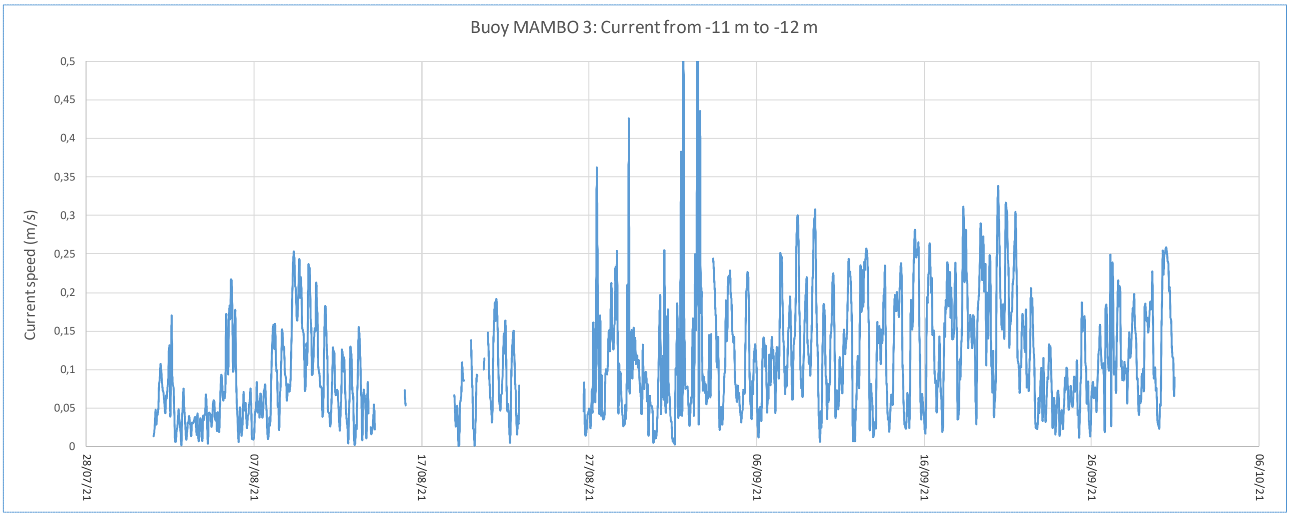


Figure 17 - Current intensity registered from 11 to 12 m depth by ADCP on the buoy MAMBO 3 from 1 August 2021 to 30 September 2021.

The following Figures from 18 to 23 show the frequency of current direction during the period of continuous recording. The most frequent direction of the current was in the sector from 210° to 240°, corresponding to South Western sector, and it was more evident at the bottom.

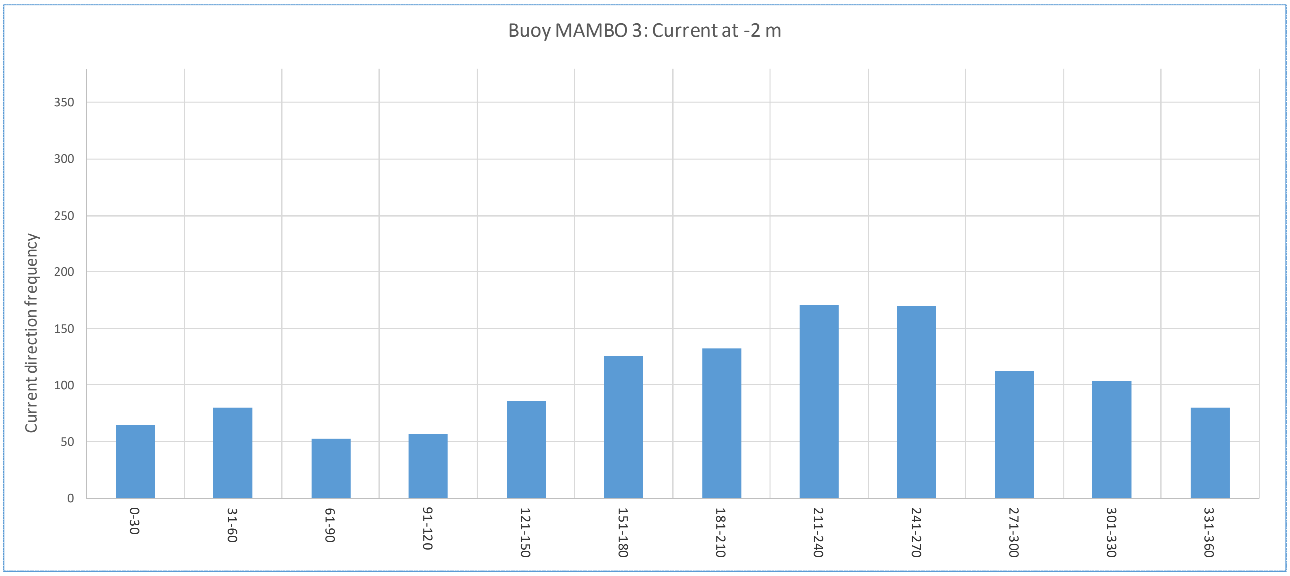


Figure 18 - Current direction registered at 2 m depth by ADCP on the buoy MAMBO 3 from 1 August 2021 to 30 September 2021.

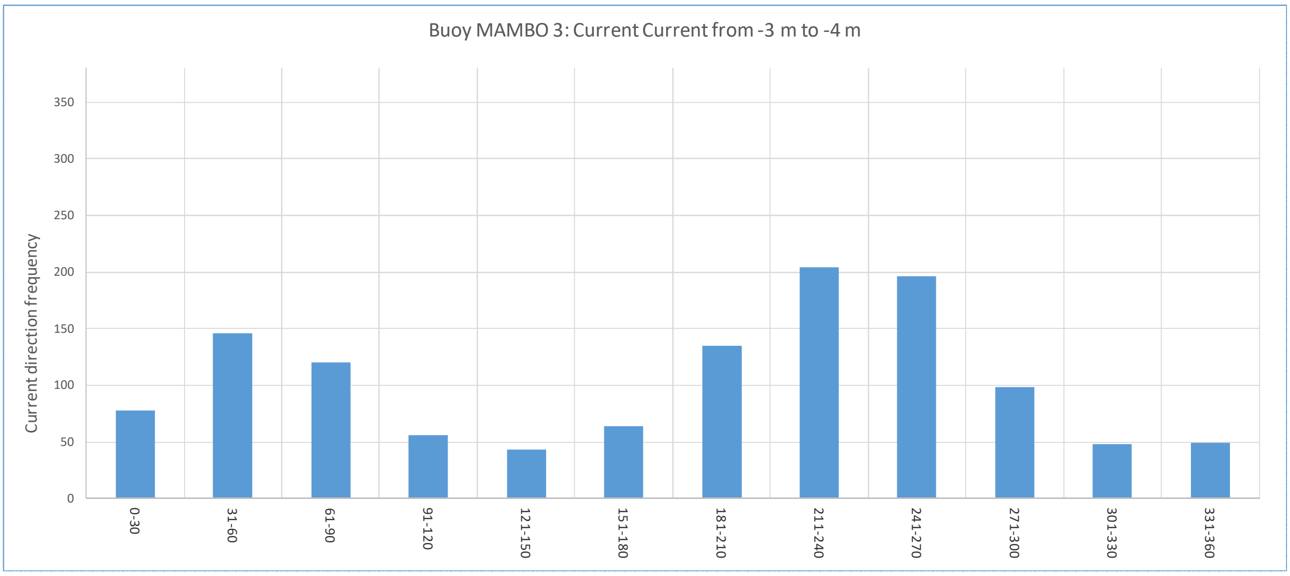


Figure 19 - Current direction registered from 3 to 4 m depth by ADCP on the buoy MAMBO 3 from 1 August 2021 to 30 September 2021.

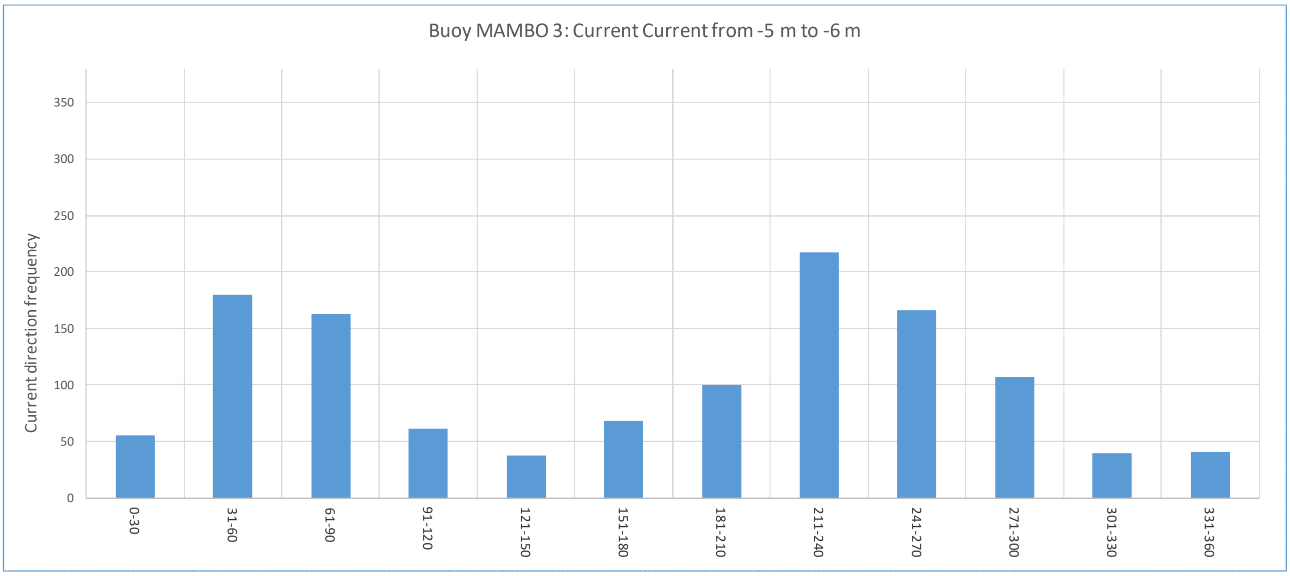


Figure 20 - Current direction registered from 5 to 6 m depth by ADCP on the buoy MAMBO 3 from 1 August 2021 to 30 September 2021.

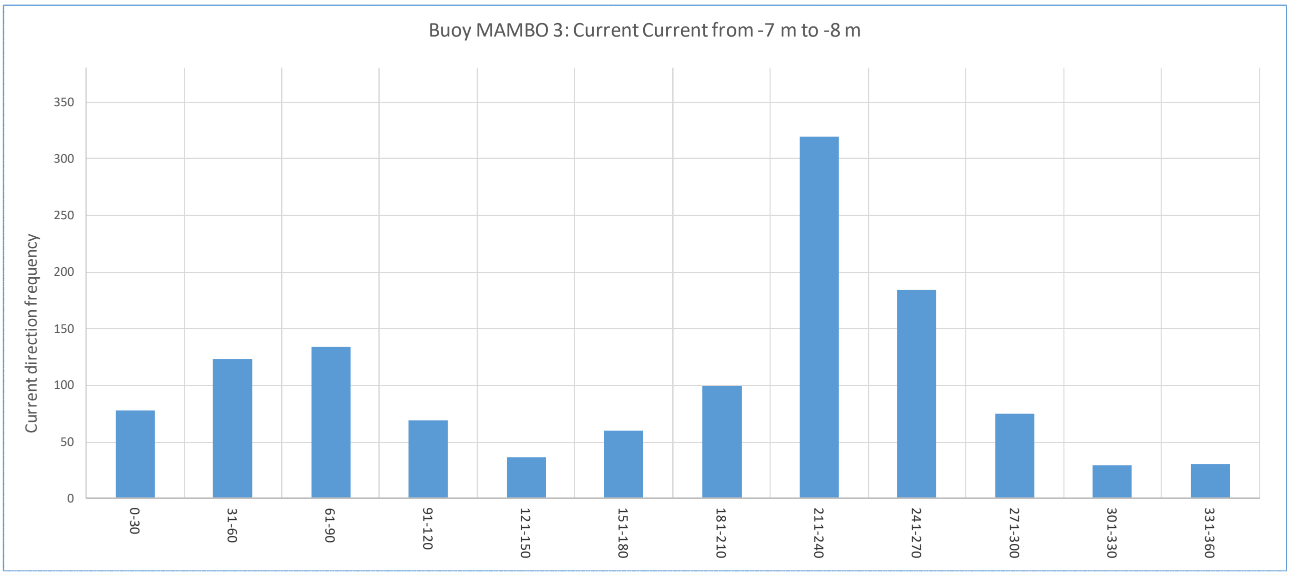


Figure 21 - Current direction registered from 7 to 8 m depth by ADCP on the buoy MAMBO 3 from 1 August 2021 to 30 September 2021.

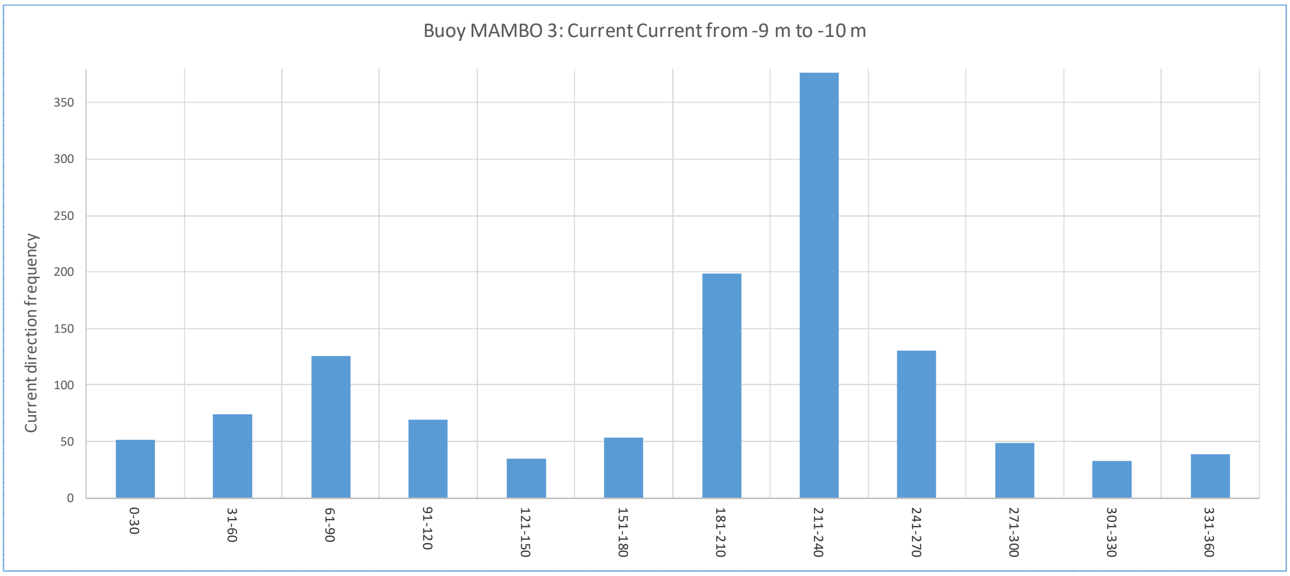


Figure 22 - Current direction registered from 9 to 10 m depth by ADCP on the buoy MAMBO 3 from 1 August 2021 to 30 September 2021.

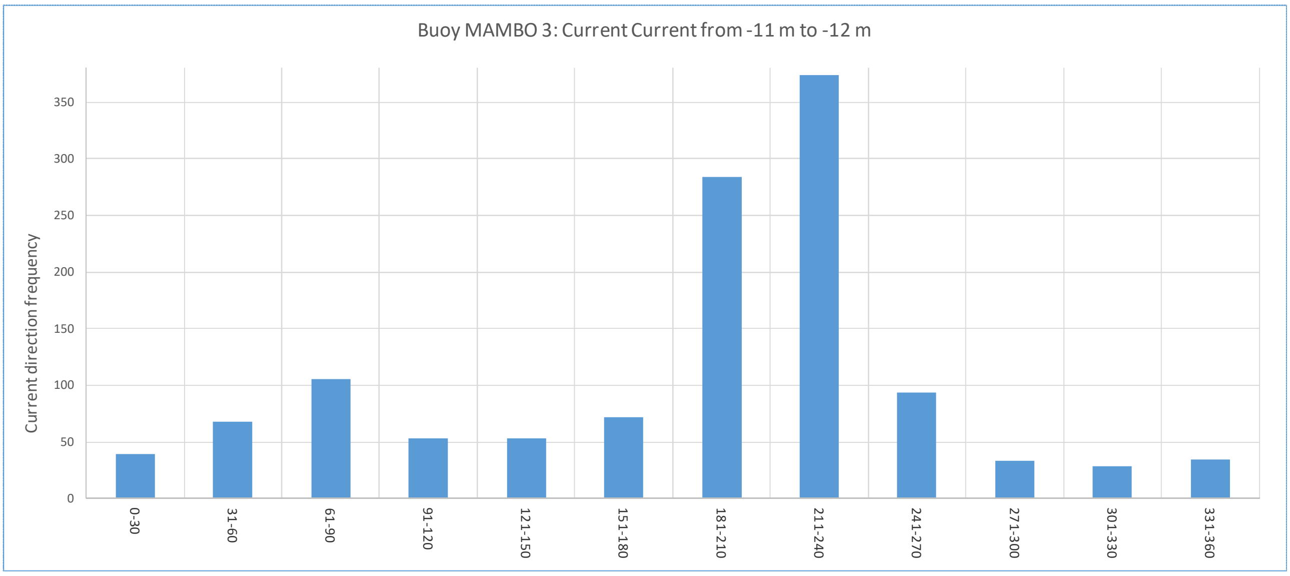


Figure 23 - Current direction registered from 11 to 12 m depth by ADCP on the buoy MAMBO 3 from 1 August 2021 to 30 September 2021.

4.2. Water column parameters

On the buoy MAMBO 2 the surface temperature was registered continuously from 1/8/2021 to 30/9/2021 and data were sent each hour. Surface temperature shows a progressive cooling from the beginning of August to the end of September, with values ranging between 20.6°C and 29.8°C (Figure 24).

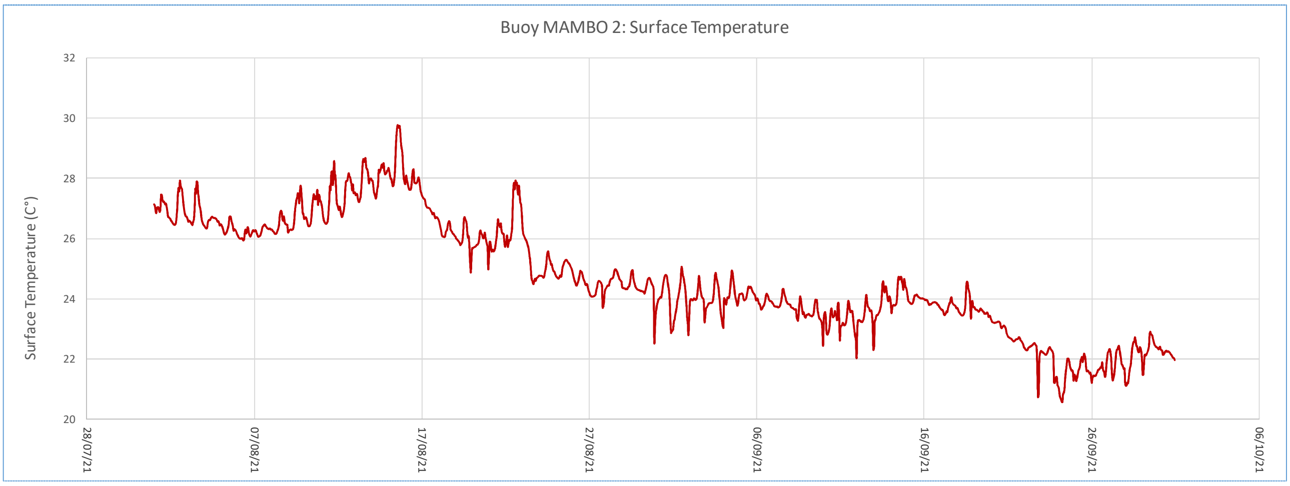


Figure 24 - Temperature at surface registered on the buoy MAMBO 2 from 1 August 2021 to 30 September 2021.

Surface temperature on the buoy MAMBO 3 shows a progressive cooling from the beginning of August to the end of September, with values ranging between 20.6°C and 28.7°C (Figure 25). Some technical problems caused missing data from 14 to 18 August and from 22 to 26 August.

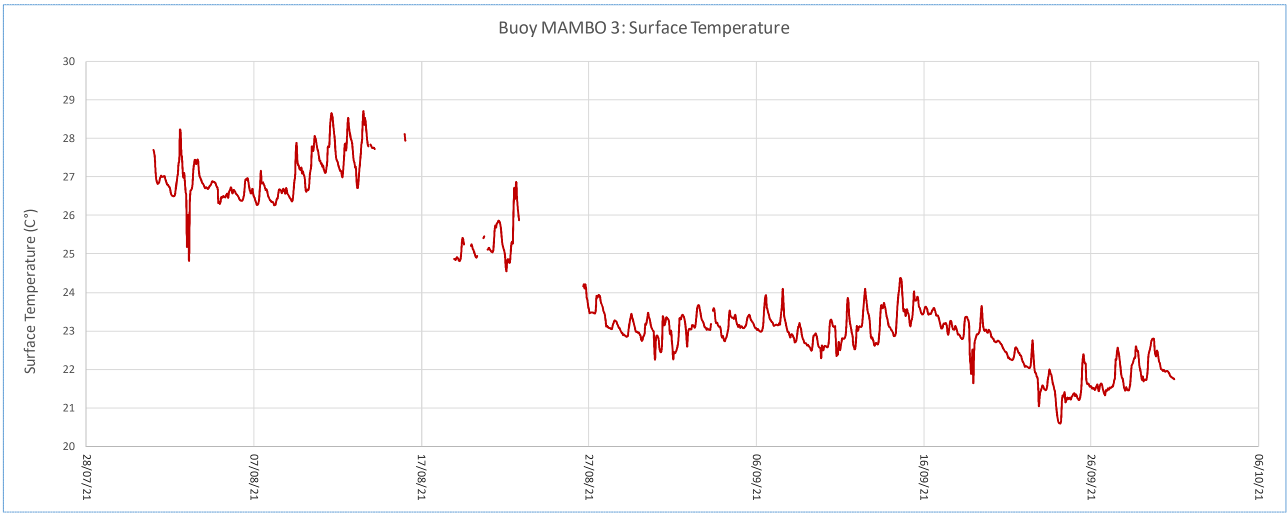


Figure 25 - Temperature at surface registered on the buoy MAMBO 3 from 1 August 2021 to 30 September 2021.

Continuous recording of water parameters at 10 m depth was carried out on the buoy MAMBO 2 by a CTD probe. The data of temperature, salinity, oxygen and turbidity recorded continuously by the sensors installed on the oceanographic buoy are shown in Figures 26 - X.

During the period from 31/7/2021 to 26/9/2021 the typical cooling of the water was observed. Temperature values ranged between 22.1°C and 26.9°C (Figure 26).

The salinity shows variable values at the beginning of August and very instable values in the second part of August (Figure 27). In September the salinity shows more stable values. The presence of less salty values is linked to the presence of water masses of river origin. The salinity values ranged from 30.0 to 37.9.

The oxygen values recorded in the two periods showed well oxygenated waters (Figure 28). The values appeared higher at the beginning of August, while 2 peaks of low oxygen were registered at 18 and 19 September. Oxygen values ranged from 192.5 to 301.6 µmol/l.

The turbidity showed values below 0,5 NTU during the first period of registration, approximately until the end of August (Figure 29). Later the registration became instable and not realistic, with peaks of values becoming higher and more frequent. This situation may be due to the fouling on the probe or its covering by sediment/particles.

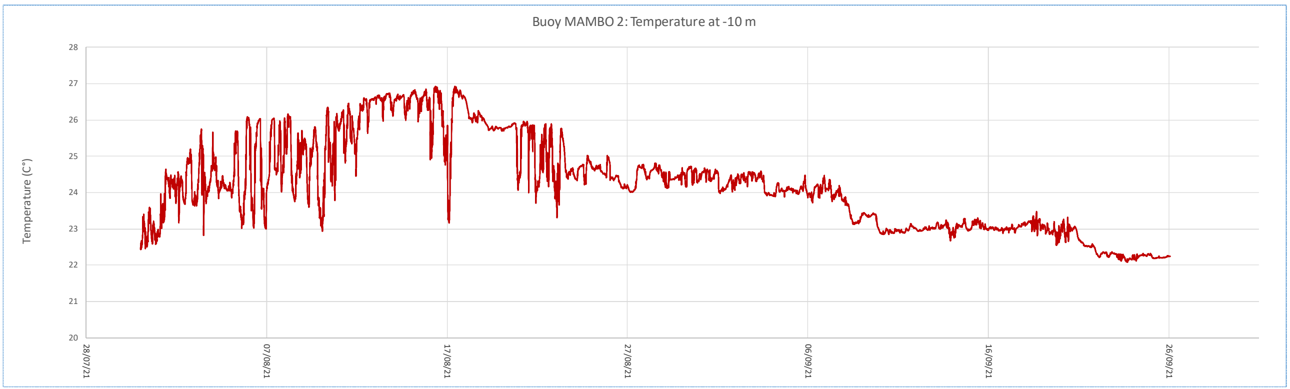


Figure 26 - Temperature at 10 m depth on the buoy MAMBO 2 from 31 July 2021 to 26 September 2021.

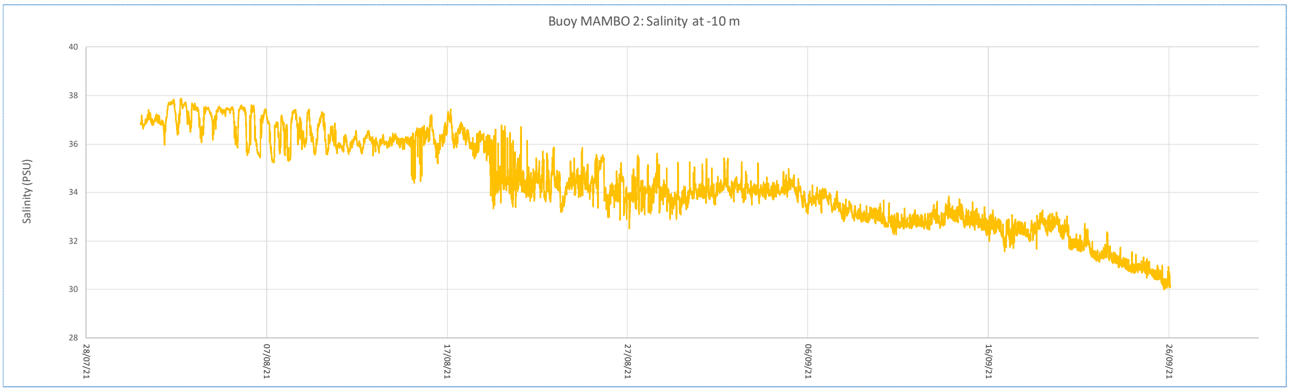


Figure 27 - Salinity at 10 m depth on the buoy MAMBO 2 from 31 July 2021 to 26 September 2021.

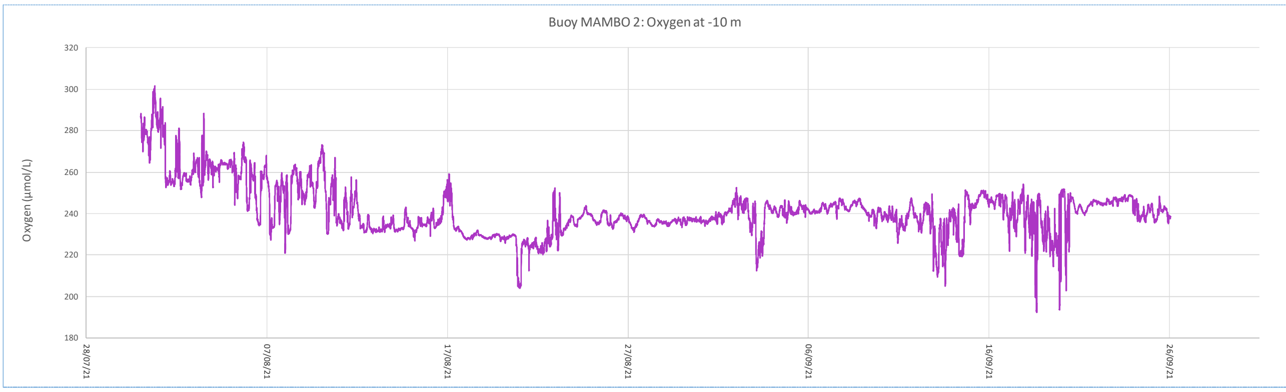


Figure 28 - Oxygen at 10 m depth on the buoy MAMBO 2 from 31 July 2021 to 26 September 2021.

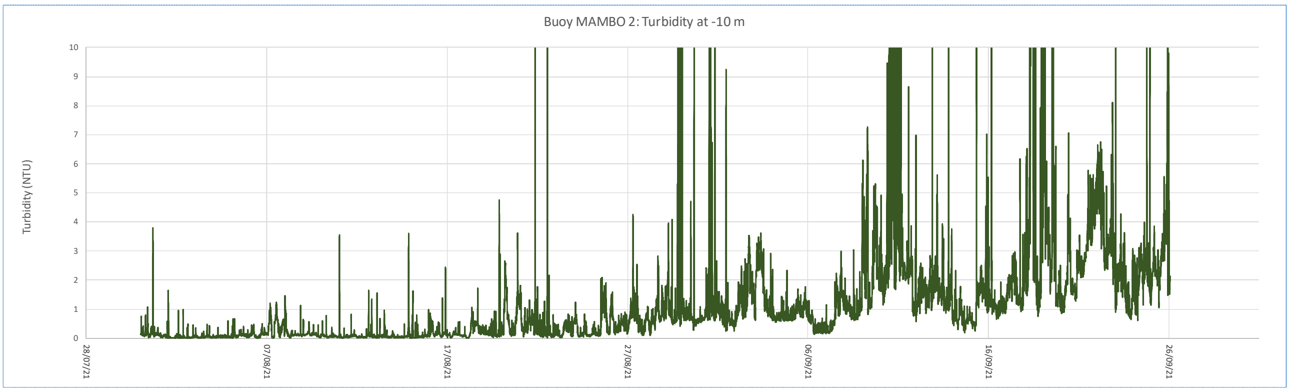


Figure 29 - Oxygen at 10 m depth on the buoy MAMBO 2 from 31 July 2021 to 26 September 2021.

On the buoy MAMBO 2 the temperature close to the bottom was registered continuously from 30/7/2021 to 4/10/2021 and data were sent each hour. Bottom temperature shows a progressive cooling from the beginning of August to the beginning of October, with values ranging between 21.6°C and 26.9°C (Figure 30). Before 23/8/2021 temperature shows high variability of values, but this situation is coherent with values recorded with the other probe at 10 m depth.

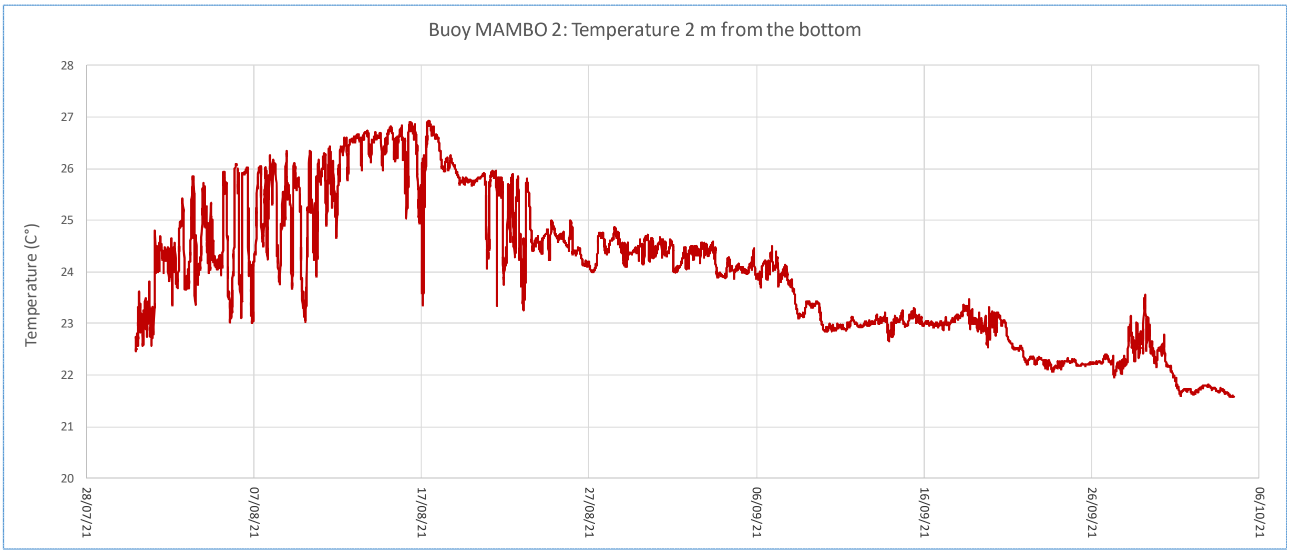


Figure 30 - Temperature at the bottom on the buoy MAMBO 2 from 30 July 2021 to 4 October 2021.

The turbidity showed values around -1 NTU during all the first month of recording (August), which means that the turbidity probe needs a correction in the calibration (Figure 31). Later the registration became instable and not realistic, with peaks of values becoming higher (reaching 320 NTU) and more frequent. This situation may be due to the fouling on the probe or its covering by sediment/particles.

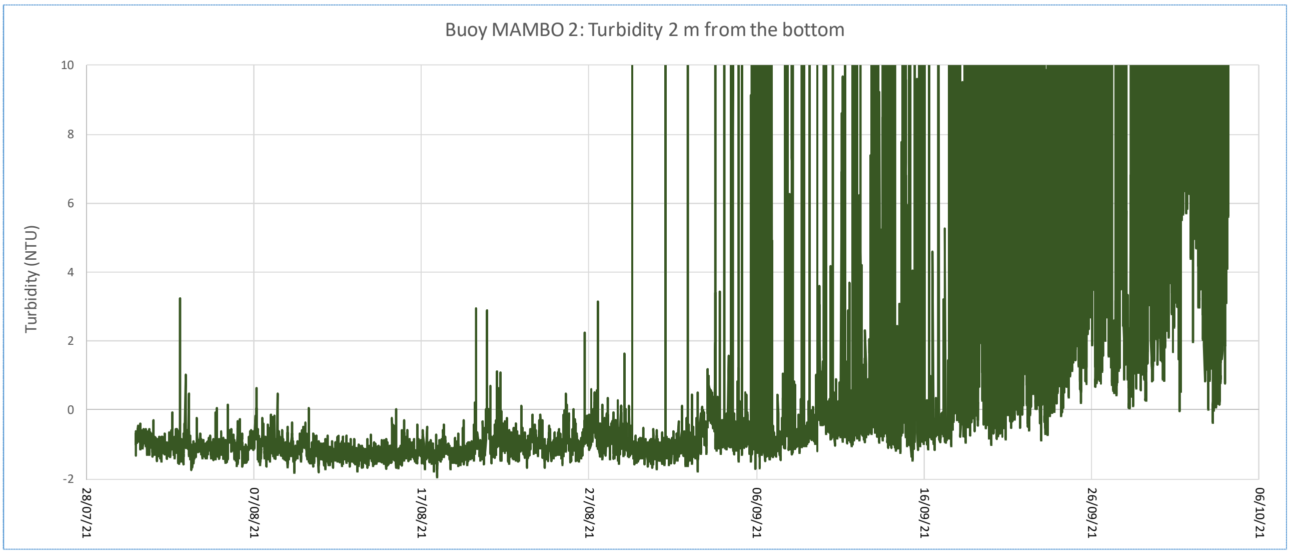


Figure 31 - Temperature at the bottom on the buoy MAMBO 2 from 30 July 2021 to 4 October 2021.

From November 2019 to February 2021, in the vicinity of the Case Study, temperature ranged from a minimum of 7.89°C, registered in February 2021 at the surface, to a maximum of 25.84°C, registered in August 2020 at the surface (Figure 32). On the bottom temperature ranged from 9.58°C (February 2021) to 23.24°C (September 2020). Generally there were not great differences between surface and bottom temperatures, except for December and January, when the surface values were 4°C and 3°C colder, respectively. In June and August, the surface values were 2.5°C and 6°C warmer, respectively. Nevertheless, there were great differences among years, since the area is quite shallow and the water column may be rapidly influenced by seasonal and meteorological events.

Salinity values along the water column were more stable (Figure 33). The exceptions were registered on the surface layers and indicate freshwater river inputs. In June the values were lower and probably linked to melting of winter snow. In October, November and December, the low salinity registered on the surface was probably due to the autumn rainy conditions.

The turbidity varied in a complex way, but was around values that remained similar between the surface and the bottom (Figure 34). It generally showed lower and more stable values in the colder months. Being the Case Study located offshore, the variability of this parameter could be linked to the river plumes with a certain time delay.

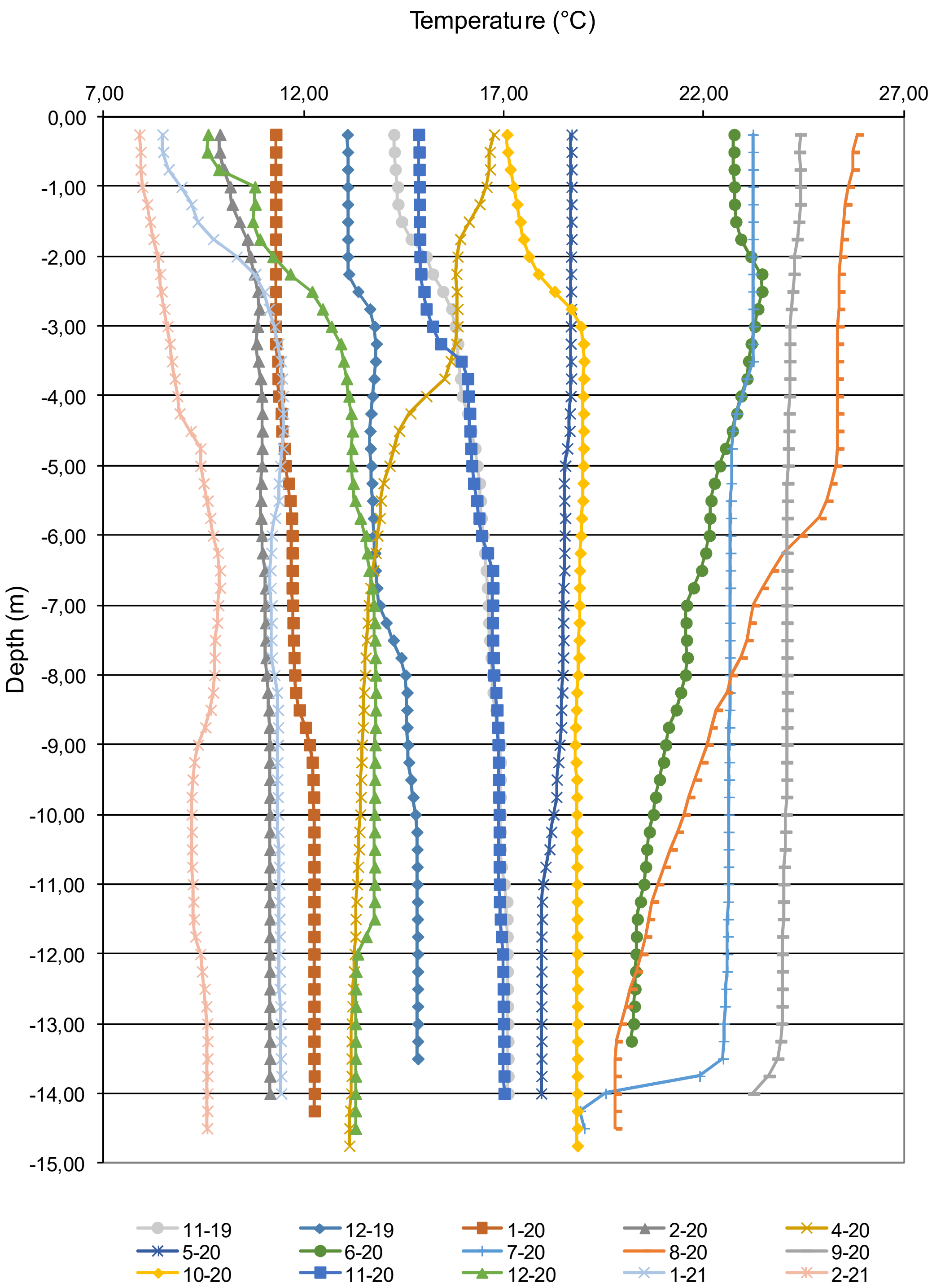


Figure 32 - Temperature profiles in the vicinity of the Case Study from November 2019 to February 2021.

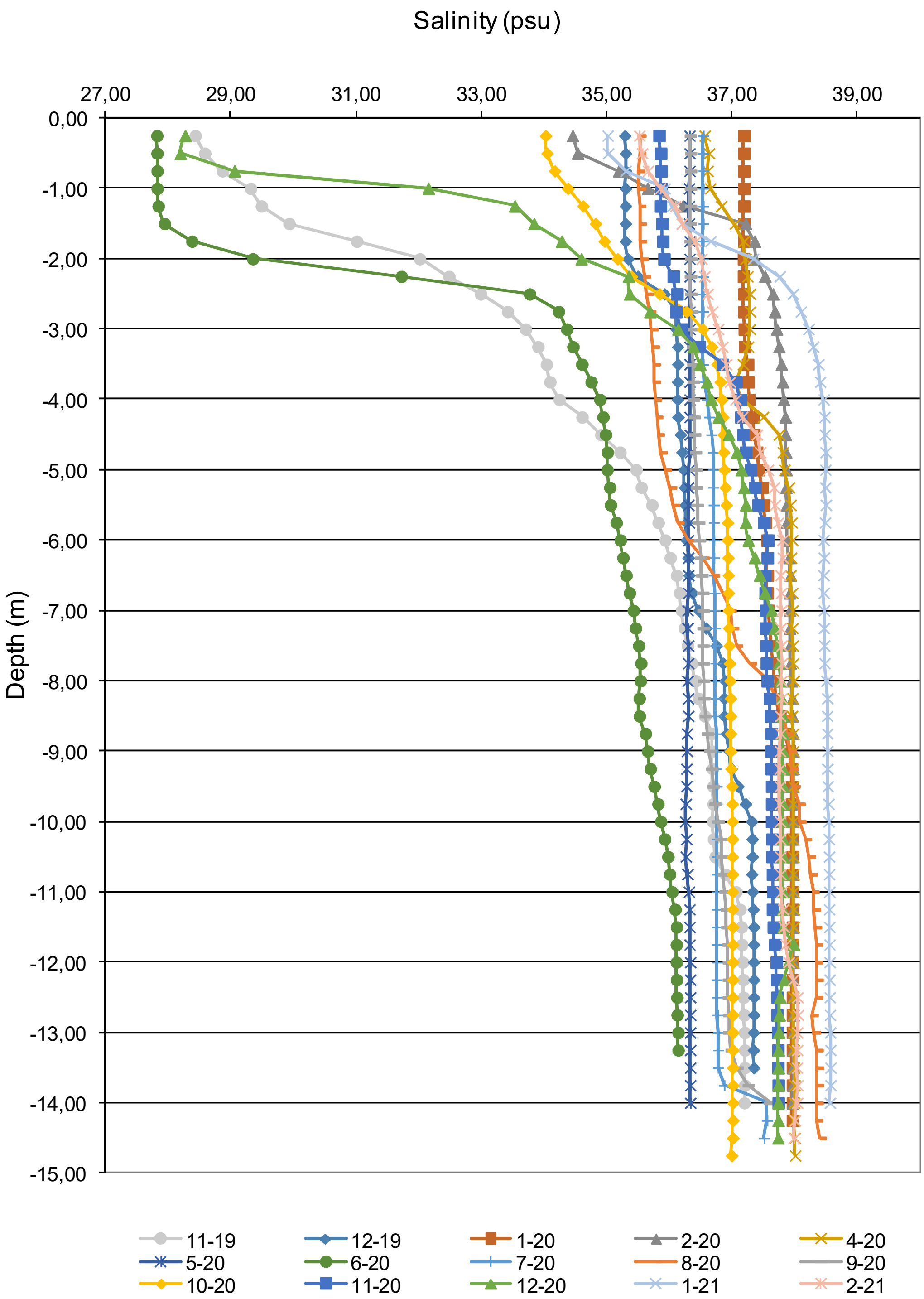


Figure 33 - Salinity profiles in the vicinity of the Case Study from November 2019 to February 2021.

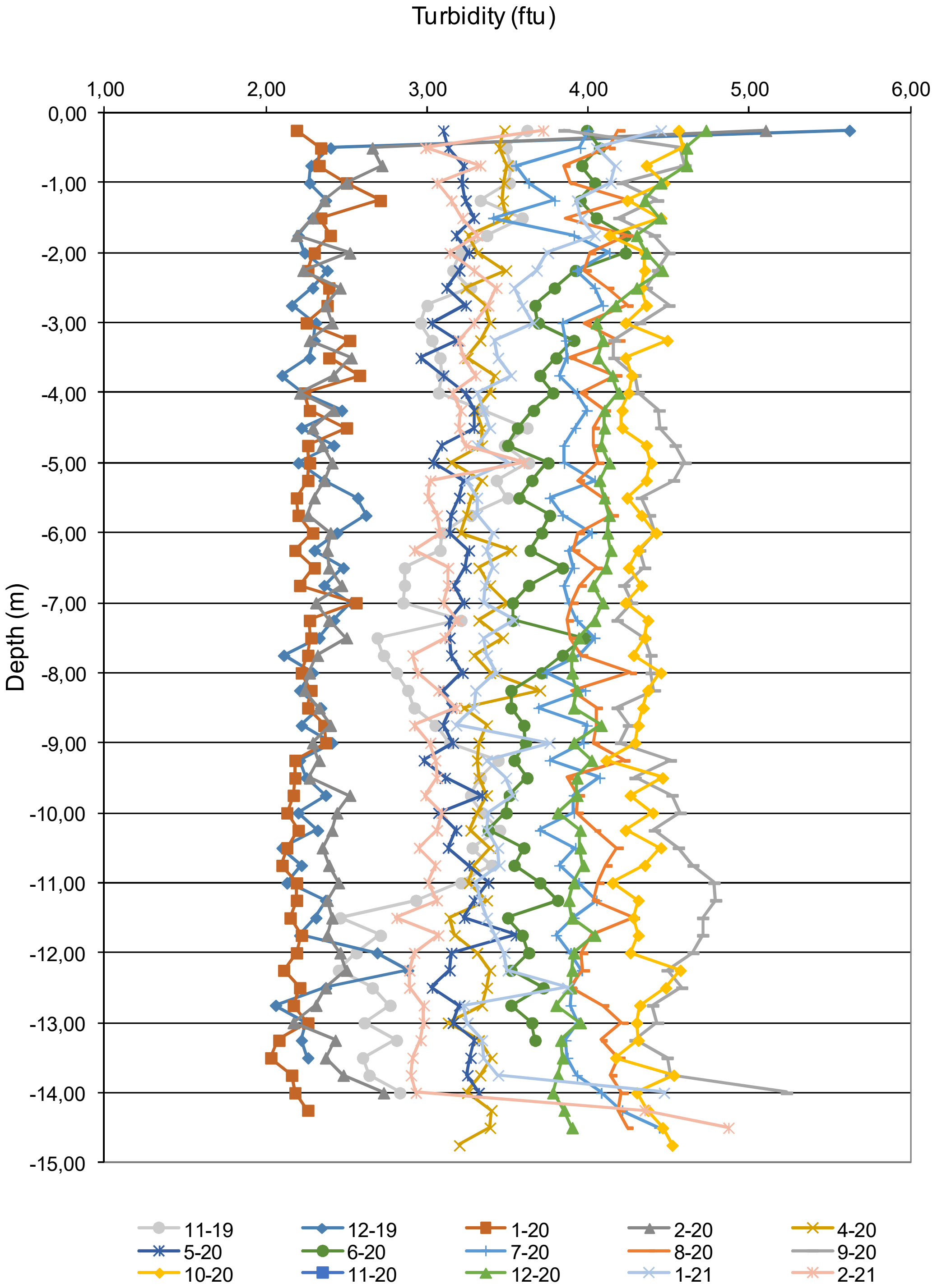


Figure 34 - Turbidity profiles in the vicinity of the Case Study from November 2019 to February 2021.

4.3. Benthic community settled on the reef

A total of 66 taxa were found on the Case Study during the winter and summer surveys conducted in 2020. The different species were: 26 Porifers, 4 Cnidarians, 5 Bivalves, 8 Gastropods, 3 Polychaets, 3 Crustaceans, 2 Echinoderms, 12 Ascidiaceans. In winter the bivalve Rocellaria dubia was the most present in the replicates, but the greatest covarage was due to the Porifer Aplysina aerophoba. In summer the most present species in the replicates was the Porifer Chondrosia reniformis together with undetermined Briozoans, while the greatest coverage was due to the Porifer Mycale sp. (Tab. 2)

Out of the 66 taxa found in the benthic community, 3 species of bivalves (Arca noae, Mimachlamys varia and Ostrea edulis) and 1 species of Poriferans (Spongia officinalis) are of commercial interest. 3 species of sponges found on the Case Study are considered by the Protocol SPA Barcelona Convention: Tethya auranthium and Geodia cydonium are included in the Annex II (List of endangered or threatened species) and Spongia officinalis is included in the Annex III (List of species whose exploitation is regulated). It should be mentioned the presence of the Cnidarian Cladocora caespitosa, which is probably the only species forming coral reefs in the Mediterranean.

The shallow depths of the rocky outcrops makes diving easy even for the beginners. Nevertheless, the great diversity of sessile fauna makes diving interesting and attractive.

Table 2 - Benthic community: list of species with relative frequency and mean coverage.

	Winter 2020			Summer 2020		
Taxon	number postive replicates	mean covarage	species number	number postive replicates	mean covarage	species number
Cyanobacteria incertae se	4	0,010				
Cyanobacteria	4	0,010	1	0	0,000	0
Axinella verrucosa	1	0,120				
Chlatria sp.				77	0,078	
Chondrilla nucula	31	0,067		28	0,152	
Chondrosia reniformis	102	0,130		77	0,157	
Cliona celata	23	0,010		10	0,020	
Cliona viridis	92	0,112		39	0,155	
Cliona sp.	17	0,010		1	0,030	
Crella sp.	3	0,017		1	0,020	
Dysidea avara	52	0,098		81	0,175	
Dysidea fragilis	4	0,013				
Geodia cydonium	9	0,326		14	0,238	
Haliclona sp.	2	0,010		4	0,023	
Ircinia variabilis	60	0,037		48	0,066	
Mycale tunicata	15	0,055		3	0,197	
Mycale sp.	122	0,101		7	0,244	
Myxilla sp.	8	0,050		2	0,020	
Oscarella lobularis	2	0,035		6	0,045	
Petrosia ficiformis	4	0,015				
Phorbas fictitius	6	0,027		7	0,036	
Phorbas tenacior	2	0,010				
Sarcotragus sp.				29	0,096	
Spongia officinalis	39	0,104		1	0,100	
Suberites domuncula	5	0,144		3	0,020	
Tedania anhelans	67	0,110		65	0,130	
Tethya auranthium	21	0,068		11	0,052	
Ulosa stuposa	1	0,120		2	0,010	
Porifera ind.	107	0,043		23	0,074	
Porifera	795	1,830	25	539	2,138	23
Cereus pedunculatus	8	0,015				
Cerianthus sp.				4	0,015	
Cladocora cespitosa	4	0,078		11	0,090	
Nausithoe sp.	1	0,010				
Cnidaria	13	0,103	3	15	0,105	2
Arca noae	13	0,021				
Lima sp.	1	0,010				
Mimachlamys varia	71	0,025		21	0,028	
Ostrea edulis	5	0,036				
Rocellaria dubia	155	0,010		64	0,011	
Bivalvia	245	0,101	5	85	0,038	2
Bittium sp.	1	0,010				
Bolma rugosa	7	0,014		2	0,020	
Calliostoma zizyphinum	23	0,010		3	0,010	
Crimora papillata	1	0,010				
Haliotis sp.	1	0,020				
Hexaplex trunculus				1	0,020	
Tylacodes arenarius	49	0,010		29	0,011	
Gastropoda ind.	1	0,010				
Gastropoda	83	0,084	7	35	0,061	4
Bonellia viridis	6	0,010		3	0,040	
Sabellidae ind.	15	0,031		4	0,010	
Terebellidae ind.	86	0,010		28	0,010	
Polychaeta	107	0,051	3	35	0,060	3
Briozoa ind.	6	0,020		77	0,033	
Briozoa	6	0,020	1	77	0,033	1
Dromia personata	4	0,095				
Maja verrucosa	1	0,020				
Pagurus anachoretus	4	0,010				
Malacostraca	9	0,125	3	0	0,000	0
Ocnus planci	1	0,010				
Ophiotrix sp.	2	0,010				
Echinodermata	3	0,020	2	0	0,000	0
Aplidium conicum	45	0,075		40	0,178	
Aplidium tabarquensis	12	0,017		71	0,027	
Aplysina aerophoba	7	0,287		16	0,237	
Cystodites dellechiajei	1	0,100				
Didemnum coriaceum	2	0,145				
Didemnum sp.	1	0,02				
Diplosoma sp.	4	0,018		4	0,025	
Microcosmus sp.	5	0,026		3	0,020	
Phallusia fumigata	17	0,017		9	0,013	
Polycitor adriaticus	7	0,109		17	0,066	
Polysincraton lacazei	8	0,054		7	0,011	
Pyura sp.	7	0,010				
Ascidiacea	116	0,877	12	167	0,578	8

4.4. Fish assemblage

A total of 20 species of Teleost fish were found on the Case Study during the seasonal surveys conducted in 2020. No Elasmobranch specimens were observed. In winter the most frequent species (number of positive replicates) were: Diplodus vulgaris, Gobius bucchichi, Parablennius rouxi and Serranus hepatus, but the most abundant (mean abundance) were: Trisopterus minutus, Diplodus annularis and Diplodus vulgaris. In spring the most frequent were: Parablennius rouxi, Gobius bucchichi and Parablennius tentacularis, but the most abundant were: Spicara maena and Trisopterus minutus. In summer the most frequent were: Diplodus vulgaris, Parablennius rouxi, Serranus hepatus and Gobius bucchichi, but the most abundant were: Chromis chromis and Trisopterus minutus. In Autumn the most frequent were: Gobius bucchichi, Parablennius rouxi, Diplodus vulgaris, Serranus hepatus and Serranus scriba, but the most abundant were: Chromis chromis and Trisopterus minutus (Tab. 3).

12 of the 20 species found are commonly commercially exploited. Sciaena umbra is the only Teleost species found on the Case Study which is included in the Annex III of the Protocol SPA Barcelona Convention (List of species whose exploitation is regulated).

The aggregating effect of the "trezze" on the fish community is determined by various factors. It is evident that the presence of solid substrate in a vast surrounding area, characterized by a sandy and muddy seabed, plays a very important role in the distribution and dynamics of the fish population, especially offering shelters to sedentary species attracted by ravines and morphological varieties. It is equally evident that the biodiversity that characterizes this type of seabed also plays a role in the presence (qualitative and quantitative) of fish species.

Most of the fish species listed above are territorial and do not move much from the point of sighting. This makes attractive the fish fauna on the Case Study, since it is easy to approach and to observe.

Table 3 - Fish community: list of species with relative frequency and mean abundance during different seasons.

Season	Winter 2020		Spring 2020		Summer 2020		Autumn 2020	
Taxon	number postive replicates	mean abundance	number postive replicates	mean abundance	number postive replicates	mean abundance	number postive replicates	mean abundance
Chromis chromis	4	3,00			7	15,95	5	12,67
Conger conger	11	0,42	8	0,33	8	0,37	7	0,43
Diplodus annularis	14	11,17	11	3,03	9	3,93	11	6,52
Diplodus puntazzo					4	0,50		
Diplodus vulgaris	18	9,07	11	5,00	18	8,11	17	7,65
Gobius bucchichi	18	3,07	16	1,94	16	1,94	18	2,28
Gobius cruentatus			9	0,67	11	0,58		
Parablennius rouxi	18	2,22	17	2,63	18	2,02	18	3,10
Parablennius tentacularis			15	0,80				
Serranus hepatus	18	1,24	12	1,64	17	1,08	17	0,98
Serranus scriba	15	0,78	10	0,63	11	0,67	16	0,96
Sciaena umbra	1	0,33	2	0,67			4	0,84
Scorpaena notata	6	0,33					11	0,48
Scorpaena porcus	2	0,33			3	0,33	3	0,33
Scorpaena scrofa			2	0,33				
Spicara maena			10	12,83				
Spondyliosoma cantharus	1	0,33						
Symphodus tinca					8	0,63		
Trisopterus minutus	11	14,85	9	10,56	11	14,24	12	12,00
Zeus faber			2	0,33	1	0,33		

5. CONCLUSION

The rocky outcrops called "trezze" represent authentic natural reserves for the reproduction and settlement both of sessile organisms, which live firmly anchored to the substrate, and of organisms that need shelter. They are also favourable environments for the reproduction and development of juvenile stages of many fish species. Thanks to the presence of cavities and interstices, these sites enhance a significant increase in marine environmental biodiversity. Taken together, these environments host benthic populations recognized as "coralligenous platform", but the large variability of conditions and ecological gradients makes it difficult to adopt a unique classification.

The "trezze" environment, of high environmental, ecological and productive value, gained the attention of the scientific world as well as of numerous categories of stakeholders, since these are sites much sought after by divers and artisanal fishermen. Nevertheless, this kind of environment is extremely delicate and vulnerable: the same hard substrate is fragile due to its calcareous and porous nature. Indiscriminate anchoring, unsuitable trawl fishing gears and even the passage of unruly divers can cause serious damage both to the sessile species and to the substratum itself. The anchoring bans, fishing with selective and non-impacting tools, the creation of underwater routes and the spread of a greater culture of respect are the tools to be adopted to protect these areas, in order to respond to the threat of environmental degradation and reduction of common natural ecosystems. The protection and conservation measures must also take into account the strong anthropogenic pressures acting on these environments, attributable to some types of fishing (in particular hydraulic dredging for the harvesting of edible bivalve molluscs) and to the quality of the water column, which is affected by the waters coming from the Isonzo and Tagliamento rivers and from the neighbouring lagoons of Grado and Marano.

6. REFERENCES

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ANNEX I - Images and data transferred at land and visualized through different media to make them accessible to the wide public

Information on the Adrireef project is available on the Institutional web site:

https://www.inogs.it/it/node/1599

In this page a brief description of the general aims of the project were presented.

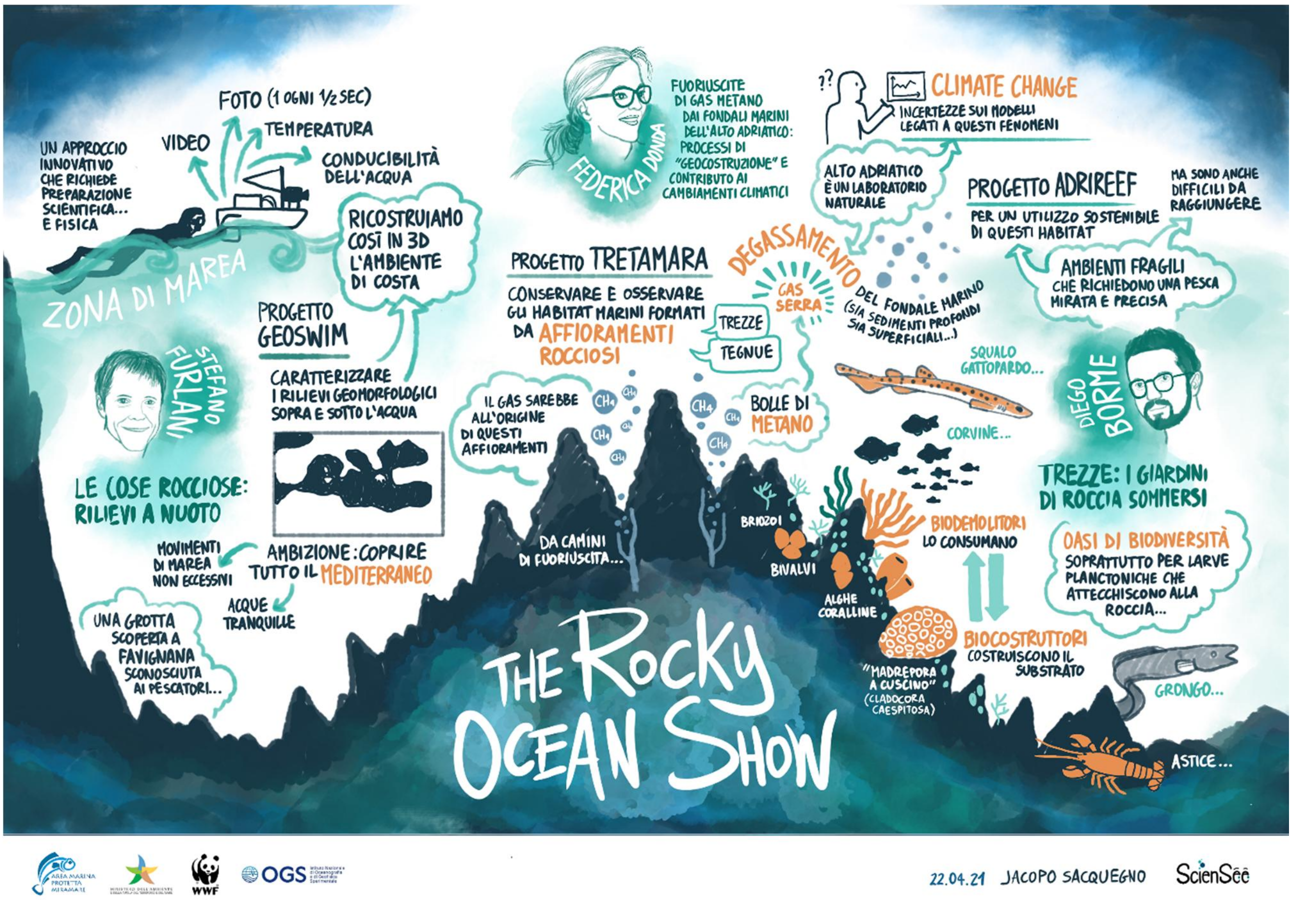
Images and data collected during the monitoring activities were used during divulgation activity comprising presentations to stakeholders, scientists and wide public.

On 22 April 2021 was presented the Webinar "Siamo in onda. The Rocky Oceans Show: Trezze -I giardini di roccia sommersi", event that reached the general public with:

- 51 participants to the webinar;
- 29 viewers of Facebook streaming of the webinar;
- 214 journalists reached with the press release to promote the webinar;
- 11279 persons reached with Facebook Event (screenshot) about the webinar;
- 449 persons reached with Facebook post on OGS official Facebook page;
- 1018 persons reached with Facebook post on OGS official Facebook page.

Annex I Figure 1 – Flyer of the Webinar "Siamo in onda. The Rocky Oceans Show: Trezze -I giardini di roccia sommersi" presented on 22 April 2020.

Annex I Figure 2 – Screenshot made during the Webinar "Siamo in onda. The Rocky Oceans Show: Trezze -I giardini di roccia sommersi" with the public reached in real time, on 22 April 2020.



Annex I Figure 3 – Screenshot made during the Webinar “Siamo in onda. The Rocky Oceans Show: Trezze -I giardini di roccia sommersi” with the public reached in real time, on 22 April 2020 showing original on-line drawing by Jacopo Sacquegno.

On 25 September, during the NEXT Trieste Science Festival (24-26 September 2021), was presented the public event “Take with care: la ricerca marina a support della salute del mare”. At the event Diego Borme presented Adrireef project and other representative from other INTERREG projects have been involved. This event reached the general public with:

- 52 participants to the public event;
- 70 viewers of the video of the public event available on Youtube https://www.youtube.com/watch?v=NGRkFcXKong&t=3277s;
- 728 persons reached with Facebook post about the public event.

During this presentation the natural reef of the Case Study “Trezza di San Pietro”, a video clip and some images of the fauna living inside the NR, were shown to the public.

Annex I Figure 4 – Screenshot from OGS Facebook page made during the presentation “Take with care: la ricerca marina a support della salute del mare”, during the NEXT Trieste Science Festival on 25 September.

Annex I Figure 5 – Pictures made during the presentation “Take with care: la ricerca marina a support della salute del mare”, during the NEXT Trieste Science Festival on 25 September.